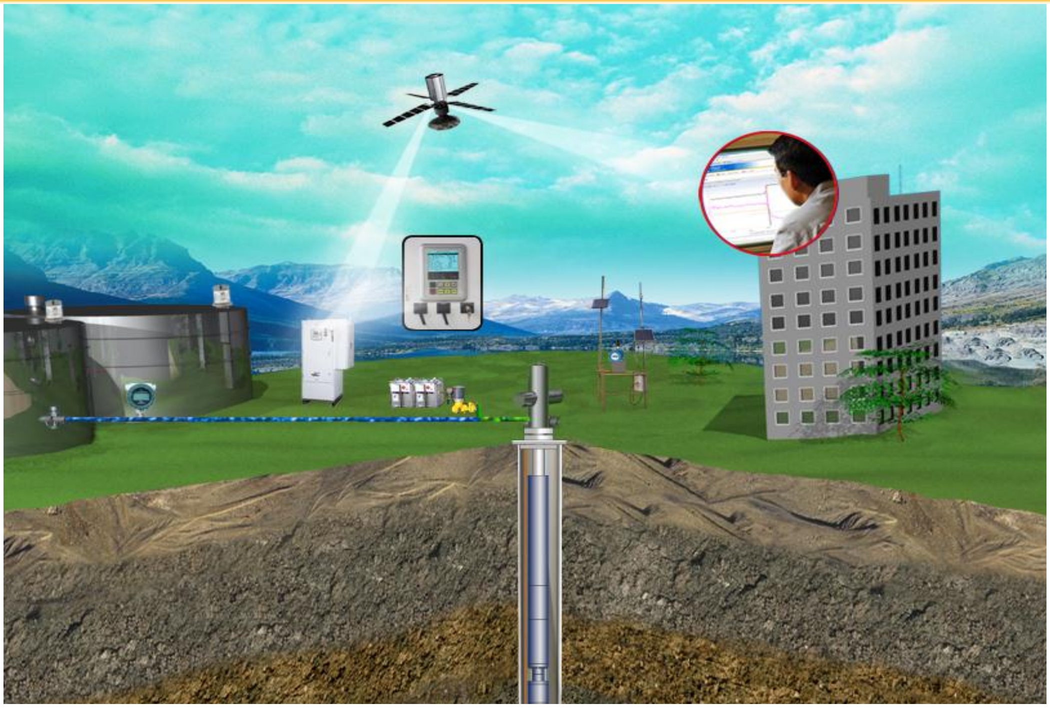
Electrospeed Advantage Drive

Troubleshooting Manual



2000/4000/8000 Series Drives
6-, 12-, and 24-Pulse
ESP (6-Step) and FPWM
NEMA 1 & 4 Enclosure

BAKER HUGHES

Electrospeed Advantage™ Variable Speed Drive
Troubleshooting and Applications Manual

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Contact your local Baker Hughes representative for current information regarding this product.

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1 Foreword

This manual contains information regarding the troubleshooting of the Electrospeed Advantage™ variable speed drive (VSD). Although some of the following information is specific to electrical submersible pumps (ESPs) and the unique characteristics presented by these applications, much of the information is applicable to all types of electric motors. Any person responsible for the maintenance of variable frequency drives can gain valuable insight from the information presented herein.

The Advantage series of VSDs is an evolution to the previous series named Electrospeed III GCS (graphic control system). Most of the circuit boards have been redesigned and many components have been upgraded to modern technology. Any reader familiar with the maintenance and troubleshooting of the GCS drives will find the Advantage drive operates and is repaired in essentially the same fashion.

The first section of this manual, Electrospeed Advantage General Troubleshooting, contains troubleshooting and diagnostic procedures specific to the Electrospeed Advantage control system. Subsequent sections provide insight into ESP Motor Troubleshooting and Data Storage Troubleshooting.

2 Safety Recommendation

The controller should be serviced by qualified electrical maintenance personnel. Improper maintenance of the controller may cause injury to personnel or equipment. The controller must be grounded in accordance with local and national electric codes. Potentially lethal voltages exist within the cabinet. Extreme care must be taken to ensure all power sources are disconnected before starting maintenance and repair jobs.

Whenever a drive containing a SCADA or telemetry connection is to be repaired or serviced, the service man must disconnect any communication devices attached to the drive to prevent unexpected start commands from the remote control system. Service men must be aware that there could be more than one remote telemetry connection and that all of them must be disabled or disconnected for the duration of the repair period. Once repairs are completed, the telemetry connections should be reestablished.

Shock and Arc Flash Hazards

The Electrospeed Advantage series of drives pose a shock and arc flash hazard when the cabinet door is open and power is applied.

Personal Protective Equipment

The basic personal protective equipment (PPE) required for field service includes: steel toe shoes, safety glasses, and a hard hat.

When working on the Electrospeed Advantage VSD with the power on, the cabinet door open and/or any access panels/shielding removed require a greater degree of PPE. Ensure the PPE worn complies with all local safety standards for live electrical work. As an example, for live electrical work performed in the United States, NFPA 70E is the industry standard.

Electrical Disconnect Handle With Interlock and Override

The electrical disconnect has an interlock feature which will not allow it to be turned on unless the cabinet door is closed. The technician can temporarily override this safety feature by turning the interlock with a slot screwdriver. This allows the cabinet door to be opened while the drive continues to operate and power is still applied.

Safety Procedures

Work inside the cabinets should be performed with the power off. Proper Lockout/Tagout (LOTO) procedures must be used to ensure personnel safety. Isolate energy source(s) including stored sources of energy (e.g., capacitors). Confirm removal of energy source using a proven voltage indicator device.

3 Advantage Troubleshooting Guide

The Electrospeed Advantage drive has been designed so that the hardware components are modularized and grouped into logical physical locations. This eases the segregation of functional sections when identifying and troubleshooting problems. The use of multiple identical driver boards and circuits help to locate a defective circuit more rapidly by allowing direct swapping of the circuit boards. Additionally, the topology of the power conversion section is functionally the same as the previous Electrospeed GCS series of drives.

PCB Functionality

Power Supply Board

The Advantage basic power supply board (BPSB – CP/N: 906641- B Old; CP/N 908241 - A New) generates all internal power used by the drive, attenuates 480 V signals, and controls the cooling fans via relays on board.

Advantage 2000 / 4000 series, 6 and 12 pulse drives

The Advantage basic system control board (BSCB – CP/N: 906610 – B) is responsible for all basic drive functions, as well as all internal and external communications to the drive. This board is utilized in the 2000 / 4000, 6 and 12 pulse input drive series. When a drive uses the BSCB sub-assembly board, the converter and inverter signal boards used are the same model as used in the GCS series of drives.

Converter Signals Board:	CSB	CP/N: 902088 – C
Inverter Signals Board:	ISB	CP/N: 902090 – G

Advantage 4000 - 24p / 8000 series drives

The Advantage system control board (ASCB – CP/N: 904843 - B) is used in the 4000-24 pulse and 8000 series drives.

When an ASCB subassembly is used, the converter and inverter signals are handled by a new style of circuit board that mounts near the device it controls. Advantage converter signals boards (**ACSB**) and Advantage inverter signals board (**AISB**) are used to control the silicon controlled rectifier (SCR) and insulated gate bipolar transistor (IGBT) power devices by routing the control signals generated from the system control board.

Advantage Converter Signals board:	ACSB CP/N: C904366 - A
Advantage Inverter Signals board:	AISB CP/N: C905756 - B

When an ASCB is utilized and any of the four available inverter outputs will remain unused, an Inverter termination plug board (ITPB S/A: 907589) must be inserted into the empty connectors. Otherwise, the un-terminated outputs will generate constant, false IOT alarms.

All models of Advantage drives automatically record and maintain an electronic record of all system data values, settings, parameters and history. The graphic display PCB only provides keypad entry, display and user configured datalogging. By factory default, it is configured as the START/STOP switch input; however, the Advantage drive can also use user-installed general purpose switches as the control inputs.

The Advantage Auxiliary Input Board (AAIB CP/N:C904860 – B) provides additional general purpose analog inputs and outputs, digital inputs and outputs as well as the ability to

measure twelve current transformer signals when the Advantage drive is used as a filtered PWM output device. The Advantage drive's BSCB can also connect to all of the previous generation of input/output GCS modules via the CITIBus connector (C-Bus) J30.
This allows the continued use of existing I/O expansion devices such as the GCS expansion I/O, Centinel and RDCM modules. New generation expansion modules, including the Advantage display unit will connect to the system via the high-speed C-Bus connector (J19).

Diagnostic LEDs

Most of the diagnostic LEDs have an obvious function which is usually labeled onto the circuit board. For instance, all power supply LEDs indicate the presence of nominal power supply voltage levels, and the processor activity LEDs indicate that the processors are functional to the point of executing instructions. The ACSB has diagnostic LEDs indicating the presence of acceptable input voltages. The AISB LED indicates gate signals and an instantaneous overcurrent trip (IOT). An IOT LED does not automatically indicate the driver board is bad, the IGBT has failed, or the system base board is bad. It could mean any, all, or none of these possibilities. Note that a consistent IOT in one physical location can indicate a hardware failure. If this is the case, refer to the Fault/Active Alarm Chart for troubleshooting tips. Conversely, if more than one IOT LED is coming on at once, it is important to note the pattern.

Two principles are important: first, since all the current produced by the drive has to flow out of one of the output cables and return on another, it makes sense that if there is a problem, it will show up in at least two phases.

Secondly, remember all the current that the inverter is dealing with has to come through the converter. Because of this, when the operator begins to have IOT problems, the first thing to note is whether the IOTs consistently show up in the same place. If they do, then the problem is likely in the load or in the inverter hardware. If not, the problem is more likely in the converter or power system related.

Converter Problems

Any disturbance in the converter (whether hardware problems or power system transients) will cause a change in DC bus voltage. Since the frequency must follow the voltage–this means that if the DC bus voltage goes up–there will be extra current on the output as the drive tries to accelerate the motor. This can happen at any instance, and because there is no correlation between which output device is on and the converter disturbance, any of the IOT circuits can detect a problem. In this situation, check the converter hardware (SCRs, gate leads, converter signals boards, system base board) and repair as needed. Also, as noted earlier, suspect the power system including all connections leading to the drive and input transformer.

Inverter/Load Problems

Logically it would seem if there is a problem with the load connected between phase A and phase B on the output of the drive, an IOT would always appear on these phases in the drive. Unfortunately, that is not always the case. This is especially true with some arcing faults, which occur because there is an element of time involved as well (due to cable and transformer inductance). Occasionally the actual fault may be delayed in time, and due to this the fault may appear to move from phase to phase. However, if you note the pattern, it will normally tend to show up in a predominant pattern (A-B, A-B, A-B, A-C, A-B, etc.). In these cases it can be helpful to rotate the output cables to the drive (A moves to B, B moves to C, and C moves to A) to see if the problem follows the cables. Remember: even if the fault is secure between A and B phases, it might show up on either the positive or the negative cycle. This means any pair of four LEDs could turn on to indicate only one problem.

4 General Troubleshooting Procedure

Always begin by observing the diagnostic LEDs on the boards. With power applied to the drive, there should be two LEDs visible on the power supply board: one on each of the inverter signals PCBs, two steady LEDs, and two blinking on the system base board. In addition, the display should have at least one LED on (either steady or blinking) and the main menu screen should be displayed. If there are I/O modules present, there should be one steady LED visible from the outside and a blinking LED visible through the opening. The proper operation of these LEDs indicates nominal operation of all of the local power supplies, and normal processor activity.

Once this level of operation has been achieved, the next step is to perform a no-load test. Verify the drive will regulate the output voltage correctly (half voltage at half frequency, etc.) and it will reach full voltage without generating a fault. It is important this test be performed with nothing tied to the output terminals. Even an unloaded transformer can add to the confusion during trouble diagnosis.

No-load Test

Disconnect all cables from output of drive (a test on an unloaded transformer might confuse the results of the test if the transformer has problems). Enable converters by moving the enable switches.

Setup is as follows:

- In Faults & Alarms menu, set:
  - Overload Setpoint= Maximum Current
  - Underload Alarm Enable= No
  - Low Speed Trip Alarm Enable= No
- Basic Setup menu, Drive Setup page, set:
  - Frequency= 30.0 Hz
  - Run I-Limit= Maximum Current
  - VClamp= 500
  - Inverter Mode= ESP/6-step
- Scroll down to Advanced Setup and press ENTER to access the following parameters:
  - Boost Sync= 0
  - VBoost= 0

Set SUT rated voltage and SUT voltage at 60 Hz to the required values according to the equipment and power available on site.

Press START. The status screen and run LED should show the status as running, all inverter and converter signal LEDs should be on. Verify frequency and output voltage ramp smoothly from minimum to 30 Hz and 50% of the user-set SUT rated voltage (a sudden jump of voltage and frequency after start accompanied by a thump from the drive could indicate converter problems). The Output voltage should be approximately 50% of full output voltage expected for the load. Frequency and voltage should be relatively steady. Note that a small amount of hunting or oscillation of the voltage and frequency can occur—this is not a problem. It should be a few tenths of a hertz to a maximum of a hertz.

Adjust set frequency to 60 Hz. Frequency and voltage should ramp to 60 Hz and 90–100% of the full output voltage for the load at the rate set by the Accel Time parameter (this parameter sets the time from 0 Hz to 60 Hz).

Press STOP and verify the drive slowly ramps to a stop then shuts off. Since the drive is completely unloaded, it will take some time for this to occur and is not affected by the Decel Time parameter (unless the Decel Time is set to an extremely long value).

If the drive will operate properly at no-load, the next test to perform is the shorted output test. The purpose of the shorted output test is to verify that both the inverter and converter sections will produce rated current. While operating the drive in shorted output, verify all three output currents and input currents are approximately balanced and stable. In addition, verify there is no significant DC component to the currents (this is evident by the fact that a clamp on ammeter will appear to stick in the closed position). Any excessive DC would indicate a device not turning on. IOTs during this test will normally indicate hardware problems (refer to the Diagnostic LEDs section and the IOTs Fault/Active Alarm Chart).

Shorted Output Test

Connect shorting cables to output of drive or secondary of step-up transformer. Ensure converter(s) is (are) enabled.

Setup is as follows:

- Faults & Alarms menu, set:
  - Overload Setpoint= Maximum Current
  - Underload Alarm Enable= No
  - Low Speed Trip Alarm Enable= No
- Go to Basic Setup menu, Drive Setup page, set:
  - Frequency= 30.0 Hz
  - Run I-Limit= Maximum Current
  - VClamp= 500
  - Inverter Mode= ESP
- Scroll down to Advanced Setup and press ENTER to access the following parameters:
  - Boost Sync= 0
  - VBoost=0
  - Sync ILimit= Maximum Current
  - Sync Frequency= 15.0
  - Sync Delay= 6 seconds

Press START. Drive should start and output current should reach ILimit Sync value for the length of time set by Sync Delay and then fall to the ILimit value. Output currents should be balanced, stable, and free of DC.

If drive trips in IOT during Sync Delay, reduce ILimit Sync by 10%. Under some field conditions, peak current may be slightly reduced.

The drive can either be allowed to run continuously in this mode or cycled by setting the Underload setpoint to slightly higher than the ILimit value and setting the restarts to Infinite.

IGBT Testing

The only way to completely test IGBTs in the field is to see if they work in the drive. When testing an IGBT, first make all terminal-to-terminal measurements using the diode scale on the meter. These should read *open circuit,* with the exception of the measurement from collector-to-emitter with the positive lead on the emitter. This reading should be the forward drop of the internal parallel diode or about 0.3–0.4 V. Next, change to the ohm scale and check gate to emitter. The effect of the gate capacitance is visible if looked at quickly when connecting the leads. The display should show a rapid change from low to high resistance as it charges the internal gate capacitance. If the leads are then reversed, the same will be visible.

With an ohmmeter, about the most the operator can be sure of when testing power devices is that they are not dead-shorted. Take caution when pronouncing devices bad because they measure 6 megaohms instead of 10 megaohms.

When repairing a drive, it is important to note that failed IGBTs will likely cause damage to the inverter signals boards. The normal failure mode of an IGBT results in the full bus volts being applied to the gate leads of the ISB. This will either burn open the small resistors which are in series with the gate leads, or short the zener diodes that are in parallel with the gate-emitter connections. More importantly, a bad ISB can damage a new IGBT if it is not detected prior to applying power.

Checking an ISB for damage is simple. As an ISB is held in the operator's hand—so that J6 is in the lower left-hand corner—it will be noticed that there is a row of resistors and diodes positioned just to the left of J2–J5. With an ohmmeter on the low ohm scale, continuity across each component should be checked. The resistors should not read open, and the diodes should not read shorted.

Instantaneous Overcurrent Trip (IOT) Condition- Define and Measure Overview

Note: A glossary of terms used herein is available at the end of this section.

Definition: An IOT fault is triggered when the voltage drop across the IGBT transistors exceeds the limit of about 8V.

Meaning of the IOT Fault

"IOT does not indicate a failure; it indicates a condition of the system."

The IOT circuit monitors each power semiconductor in the inverter and watches for improper operation. It is important to understand the actual function of the IOT circuit is to protect the VSD and make troubleshooting simpler. Basically, the assumption is that for normal operation, when the IGBT is supposed to be on, it will look like a switch, or have a very low voltage drop. If, on the other hand, the device is asked to handle more current than it is capable of, the voltage drop across it will rise dramatically. The IOT circuit, therefore, monitors the voltage across each IGBT. When that voltage exceeds a predetermined threshold (approximately 8 V), the IOT circuit turns the device off within 1uS and sends an inhibit signal to all other IGBT gate signals as well as a stop command to the microprocessor. Because of this, within about 10–15uS of detecting a problem on one power device, the entire drive will be shut down. Note that the IOT circuit does not tell you that there has been an over current (although that will be the most common reason for an IOT) or that the device is bad. It simply tells you that there has been too much voltage drop across the device during operation.

Causes of the IOT Fault

There are four possible sources of an IOT condition.

Incoming Transient/Power Faults

Converter Hardware Faults

Inverter Hardware Faults

Load Faults

Incoming Transient/Power Faults

A transient disturbance on the power system can cause the DC bus voltage to increase rapidly. Since the VSD output frequency must follow the voltage, this means that if the DC bus voltage increases, there will be extra current on the output as the drive tries to accelerate the motor. The sudden increase of output current can result in an IOT condition.

Converter Hardware Faults

Abrupt changes to the DC bus voltage will cause changes to VSD output frequency and output current which in turn can cause an IOT condition.

Inverter Hardware Faults

The VSD output current, voltage, and frequency are dependent on proper operation and switching of the output IGBTs. Any interruption to the switching of IGBTs will result in incorrect operation which will most likely create an IOT condition.

Load Faults

Load faults are usually due to a sudden arc of electricity to earth-ground. Examples of load faults would be if one phase of the motor or cable experienced insulation failure which provides a low-resistance path to ground. Typically this will cause increased current through one VSD output phase and may result in an IOT condition.

Measure

With the possible sources of the IOT condition defined above, this section will provide a method of identifying which of the above sources is most likely to be the cause of the IOT. Please note that the process below identifies as many of the relevant steps in the source identification as possible. When Field Service assumptions can be made why a step was either skipped or combined with other steps, it is a best practice to include that reasoning in the field Service report. The flow chart in figure 1 and 2 provides the general steps in defining which direction the investigation should take in assessing each of the four sources of IOT condition as the root cause.

CAUTION

Electric Shock Hazard

Severe injury or death can occur if the following safety precautions are not adhered to.

Only qualified personnel shall perform the operations described in the procedures below.

Proper Electrical PPE and appropriate electrical safety boundaries shall be adhered to when operating the VSD with the main doors open.

Prior to performing a mechanical/visual inspection or removing any sub-components from the VSD, proper lock-out/tag-out procedures shall be adhered too.

Only properly rated test equipment shall be used when taking any electrical measurements.

Proper PPE shall be worn at all times when repairing a VSD or electrical measurements are being taken.

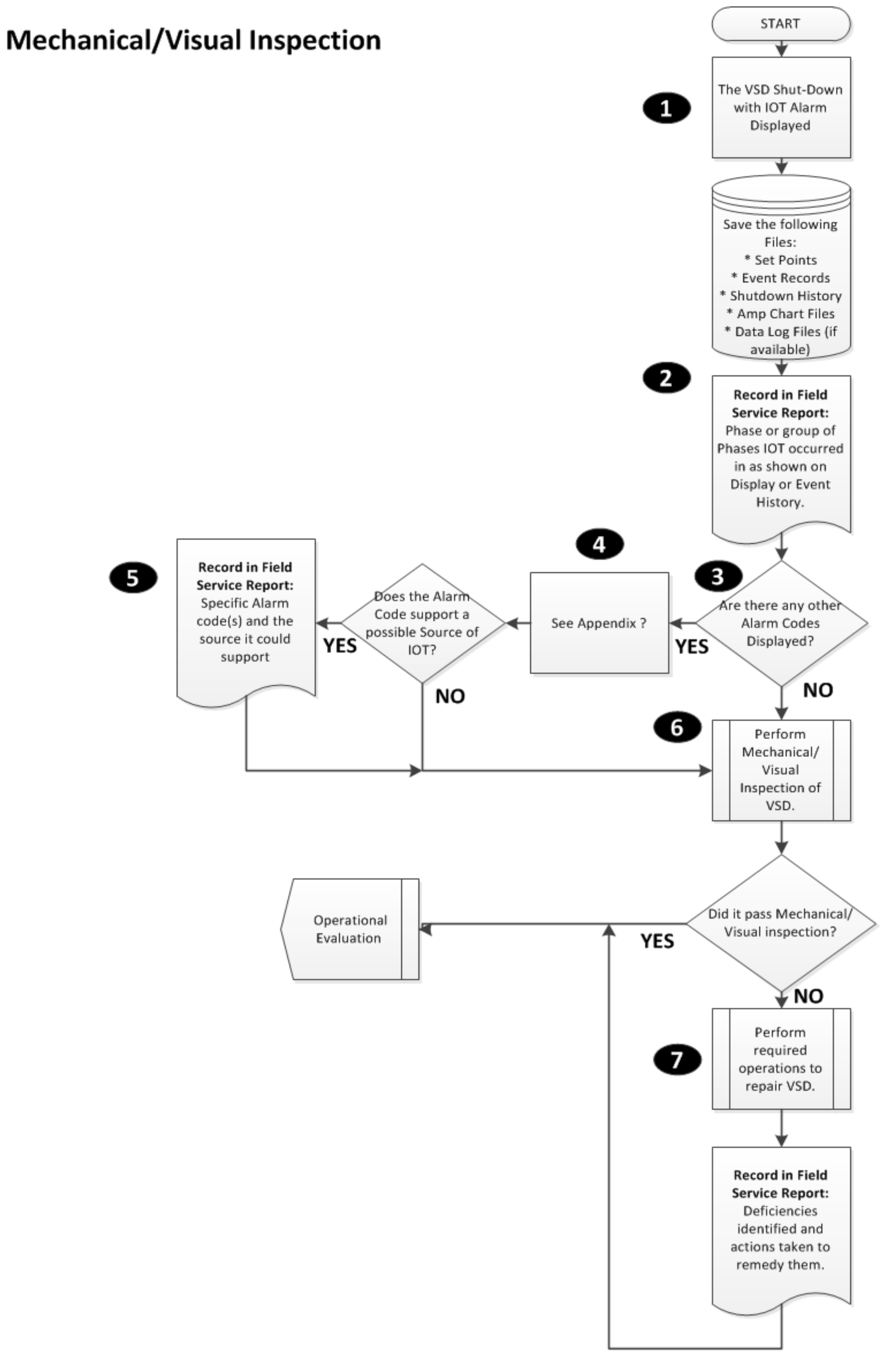


Figure 1: Mechanical/Visual Inspection Overview for all VSDs that have had an IOT Condition. The purpose of this overview is to provide general steps in narrowing down the possible Root Cause to the IOT

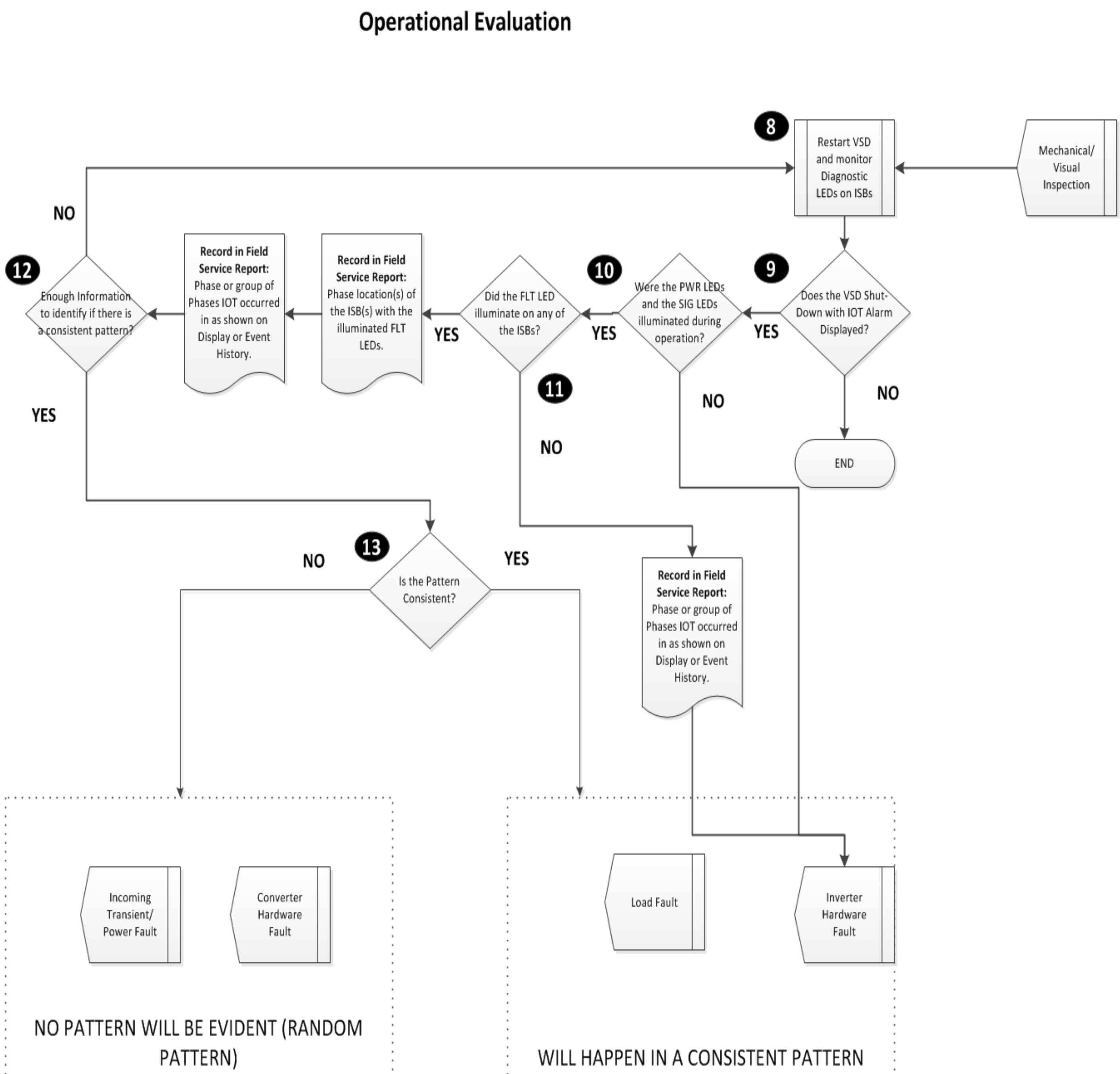


Figure 2- Operational Evaluation Overview for all VSDs that have experienced an IOT condition.

The purpose of this overview is to provide general steps in narrowing down the possible Root Cause to the IOT. This process should only be followed after the process shown in figure 1 is completed.

Table 1- Detailed Mechanical/Visual Inspection & Operational Evaluation Process

Operational Step Number	Figure Reference	Detailed Description
❶	1	**CAUTION**: Only qualified personnel shall perform the operations described in Figures 1 and 2. This process is applicable when VSD has shut-down with the IOT alarm displayed on either the GDI or the Event Shut-Down History
❷	1	It is important to save in, CSV format, the following files in their entirety. Set Point Files Event Record History Shutdown History Amp Chart files Data Log Files if available. It is recognized that not all drives are set up for data logging. In the Field Service Report it is important to document which Phase or Group of Phases the IOT Alarm was associated with.
❸	1	The IOT shutdown takes precedence over all other alarms and events to the VSD shutdown hierarchy; consequently the IOT will often shut the drive down prior to any other alarms being recorded. Under certain instances, other alarm/fault conditions may happen prior to the IOT condition occurring that can be an indicator to the root source of an IOT condition.
❹	1	Not all alarms or events correlate to an IOT condition therefore the list in Table 6 has been created to assist in telling the difference in an event or an alarm that can be used for identifying the source of an IOT and which cannot.
❺	1	Although the list of Alarms and events in Table 6 are a clue in identifying the source of an IOT, it cannot provide the entire picture. Record the results from referring to Table 6: List of Event Codes or Displayed alarms for use during the Operational inspection.
❻	1	**CAUTION:** Prior to performing a mechanical/visual inspection or removing any sub-components from the VSD, proper lock-out/tag-out procedures shall be adhered too. Refer to the section labeled Mechanical/visual inspection
❼	1	**CAUTION**: Only qualified personnel shall perform the repairs. Proper PPE shall be worn at all times when

Operational Step Number	Figure Reference	Detailed Description
		repairing a VSD or electrical measurements are being taken.
❽	2	Two questions that are useful to have answered when diagnosing the source of an IOT Alarm are. 1) Does the IOT Alarm repeat immediately (≤ 30 Sec.) on start-up? 2) Does the IOT Alarm repeat in a consistent pattern in relation to previous IOT Alarms? The only way to answer these two questions is by performing an operational evaluation.
❾	2	**CAUTION:** Proper Electrical PPE and appropriate electrical safety boundaries shall be adhered to when operating the VSD with the main doors open. Monitor the Diagnostic LEDs on the ISB using the section Inverter Signal Board LED Indicator operation for reference.
❿	2	The PWR LED and the SIG LED are diagnostic indicators for the Inverter Hardware Section only. The FLT LED is a visual indicator that an IOT condition has occurred and can happen from a root cause stemming from any of the four sources of IOTs.
⓫	2	An IOT Alarm can at times register in the Event History without the FLT LED illuminating on the corresponding ISB. The probable source for this scenario is in the inverter hardware (either the ISB or the SCB). Although unlikely, the IOT feedback hardware can be damaged and report a false IOT fault signal. The resulting event record to be recorded on the display will likely be “Unknown PCM Fault”.
⓬	2	If no other clues are available, establishing if the IOT alarm occurs in a consistent or random pattern will reduce the possible number of sources by half. To establish if a pattern exists, one may need to repeat the failure several times. **The number of times to try to repeat the IOT event for pattern recognition purposes is left to the discretion of the Field service technician based on well circumstances and other evidence that may be present at the particular well site.** It is highly recommended by the Product Center for the Field Service technician to become familiarized with the VSD shut-down history, particularly if the IOT condition has been seen as a trend in the field or particular Well Site in the past.
⓭	2	If the IOT fault repeats in a Consistent Pattern then the

Operational Step Number	Figure Reference	Detailed Description
		source will either be an Inverter Hardware Fault or a Load Fault. If a pattern cannot be identified then the source may be either be a Converter hardware fault or an Incoming Transient/Power Fault.

Incoming Transient / Power Faults

Of the four possible sources of the IOT condition, incoming Transient / Power Faults have traditionally been the most difficult to diagnose because first, of the four sources this is considered to be the least likely to be the culprit so it is often overlooked; second, the amount and type of data needed to be able to identify Incoming Transients / Power Faults as the Root Cause is often times not available upon initial investigations; third, by the fact that a one-time momentary glitch on the incoming power is impossible to replicate in the field to show the costumer makes it a hard diagnosis to be accepted; and finally four, the VSD has been designed such that it is rather robust against this sort of fault stemming from incoming power. It takes an exceptionally large dv/dt for an incoming transient / Power Fault to manifest as an IOT condition.

A supply power transient can happen at any instance, and because there is no correlation between which output device is on and the power system disturbance, any of the IOT circuits can detect a problem. This is why if one can get the IOT condition to repeat it will likely not be in a consistent pattern.

The first step in evaluating if an Incoming Transient / Power Fault as the source of an IOT condition is to perform an Environmental review, see figure 3. At times through the environmental review it may be necessary to perform an Engineering Power Study on the system, see figure 4 for a general presentation of that topic.

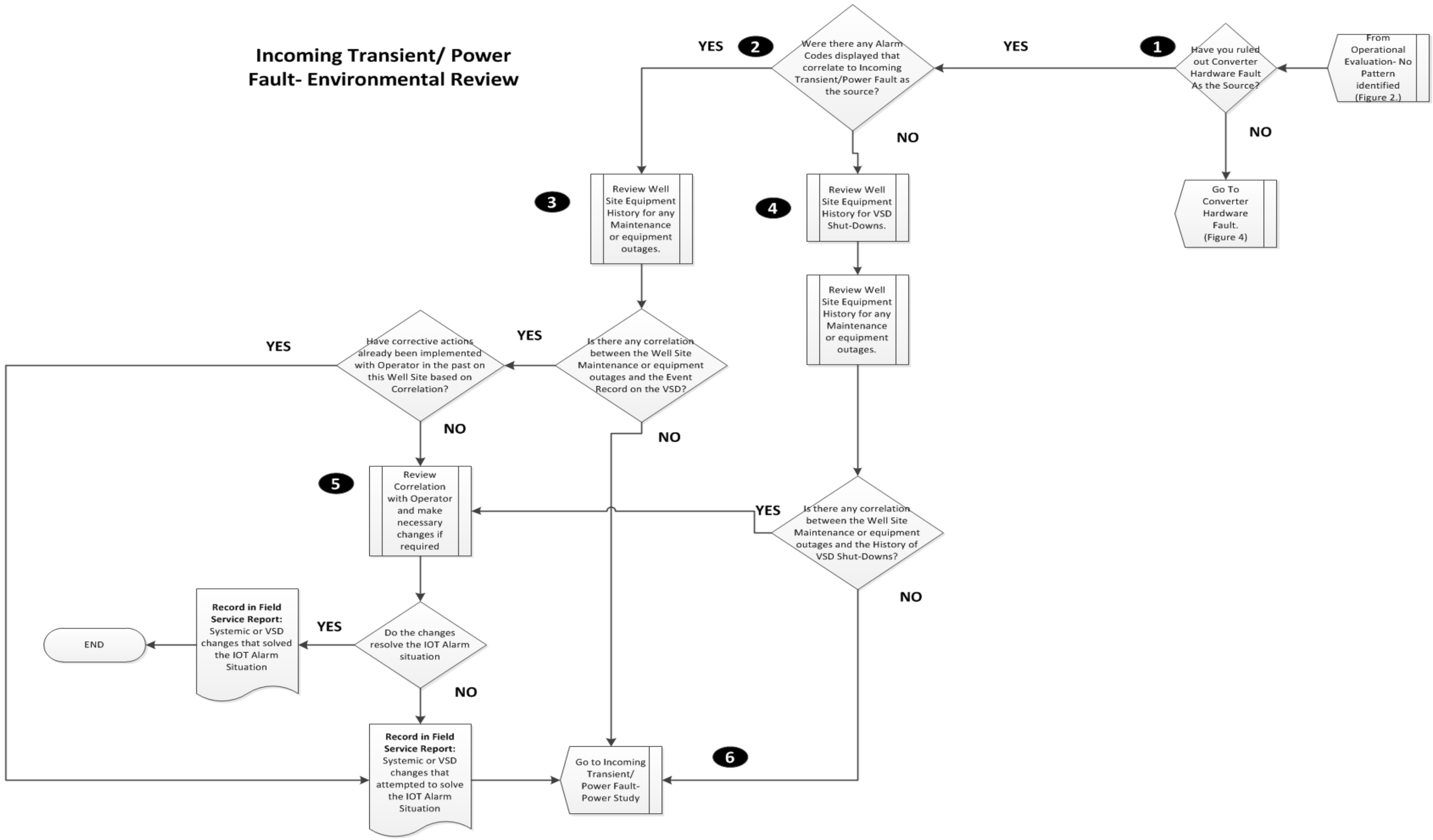


Figure 3: Incoming Transient/Power Fault Environmental Review.

This figure provides an overview of the suggested process to follow when conducting an environmental review.

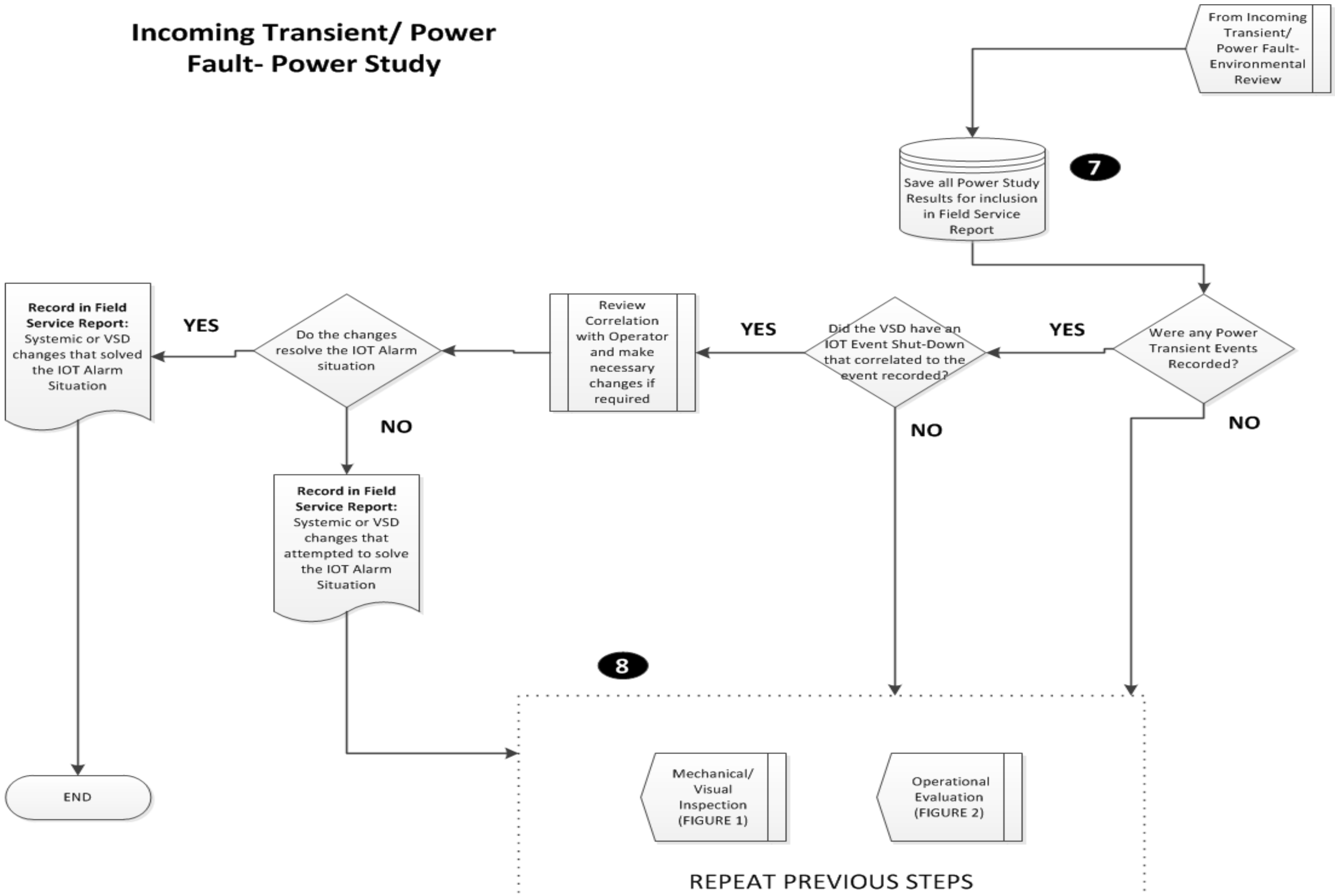


Figure 4: - Incoming Transient/Power Fault-Power Study

This figure provides an overview of the suggested process to follow when conducting a Power Study

Table 2- Incoming Transient/Power Fault

Operational Step Number	Figure Reference	Detailed Description
❶	3	Of all the Sources of the IOT condition, Incoming Power Transients is the least likely historically to be the source therefore all other possible sources should be reasonably eliminated before performing this investigation. For a Random Pattern Scenario, always investigate for Converter Hardware Faults first.
❷	3	Refer back to Operational Step Numbers 3 and 4 of Table 1 for more details. All relevant Alarm Codes should be already recorded in the Field Service Report for Reference. Review the following related drive files for trends: Event Record History Shutdown History Amp Chart files Data Log Files if available. It is recognized that not all drives are set up for data logging. It is recommended by the Product Center to use CentriGraph program to analyze data. Look for relationships between IOT and power system transients, such as 0-XING faults, Ride Through Low Speed faults, Voltage Sags, etc. (Note that Ride Through Low Speed faults and Voltage Sags are recorded only if using PCM 11r15 or higher, with compatible Sys and GDI software versions)
❸	3	Evaluate the following questions for the time around the IOT alarm occurred. Was there a planned System Shut-Down for Maintenance or other reasons? Was there an unplanned System Shut-Down(weather events, other equipment malfunction, etc)? Has any Prime Power Equipment (Step-Down Transformer, Generator Set, Switch Gear, Line Fuses, Circuit Breakers, etc.) been replaced upstream from the VSD? Has any Prime Power Equipment (Step-Down Transformer, Generator Set, Switch Gear, Line Fuse, Circuit Breakers) had a major failure? Has any Prime Power Equipment (Step-Down Transformer, Generator Set, Switch Gear, Circuit Breakers) upstream from the VSD been adjusted? Was an additional load to the Primary Power added or taken away?
❹	3	Review the previous Field Reports related to the drive in question for the following: Is there a history of converter hardware fault failures

Operational Step Number	Figure Reference	Detailed Description
		(Blown Input Fuses, Blown SCRs, etc.) Has the VSD had any unplanned stops due to Prime Power Equipment reasons (Step-Down Transformer, Generator Set, Switch Gear, Line Fuses, Circuit Breakers). Does the Drive Downloads attached to the previous Field Reports show a pattern in event history that correlates to the current event history related to Operational Step Number 1?
❺	3	The entire environmental review must be done with tight coordination with the operator and again only after all other possible sources of the IOT condition have been systematically vetted and disproved. Incoming Transient/Power faults are the only source that leads to the examination of equipment that is upstream to and often out of control from Baker Hughes. It is vital that due diligence on Baker Hughes equipment has been performed prior to going this route.
❻	3	At times there is no historical information available to perform an environmental review, or there is concern that the sampling rate of the VSD and/or the recorded data log files obtained from VSD does not capture enough detail to properly profile the Incoming Transient/Power faults that may be affecting the VSD. This is when a Power Study with more sophisticated equipment is the next course of action.
❼	4	All Power Study results are to be saved in Electronic Format with the Field Service Report in their entirety to be uploaded for future reference.
❽	4	If the resolution to the IOT situation does not appear to be traceable to Incoming Power then previous troubleshooting steps should be revisited.

Converter Hardware Faults

As with the Input Transient/Power Fault, issues with the Converter Hardware do not normally manifest into an IOT condition. As mentioned in the define section of this document when a fault occurs in the Converter Hardware that causes a large enough dv/dt in the DC bus the condition will directly affect the Output frequency and the Output Current and in turn possible lead to an IOT condition. Any situation that affects these two variables can create an IOT condition if severe enough. The process for troubleshooting an IOT condition related to the Converter Hardware section mirrors the Troubleshooting steps presented in the GCS and Advantage Troubleshooting sections concerning Converter faults. See Figures 5 (Converter Hardware-Electrical Evaluation) and Figure 2 (Converter Hardware- Operational Evaluation).

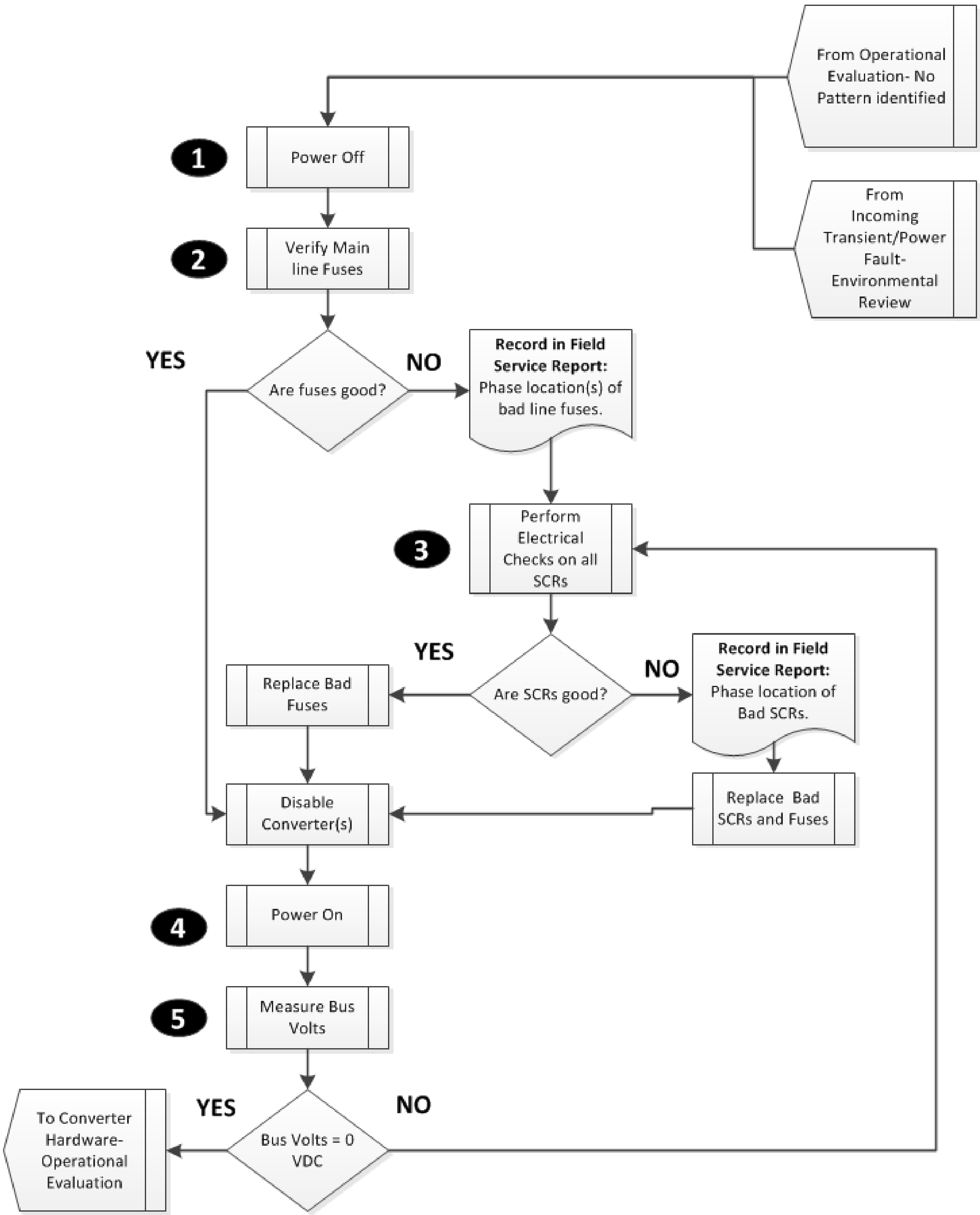


Figure 5: Converter Hardware Fault- Electrical Evaluation

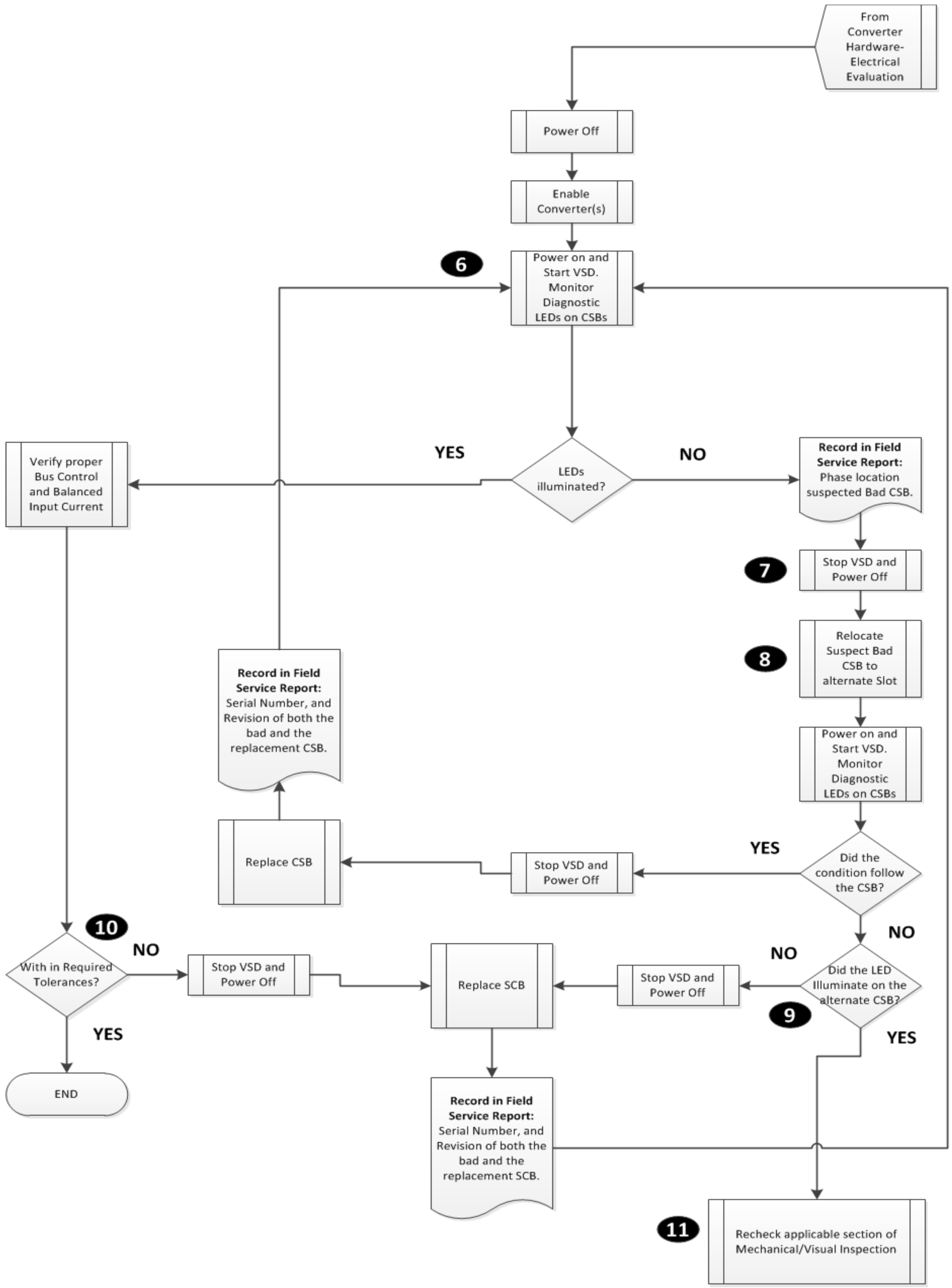


Figure 6- Converter Hardware Fault- Operational Evaluation

Table 3- Converter Hardware Fault- Electrical & Fault-Operational Evaluation

Operational Step Number	Figure Reference	Detailed Description
❶	5	CAUTION: Prior to performing a mechanical/visual inspection or removing any sub-components from the VSD, proper lock-out/tag-out procedures shall be adhered too. The Term “Power Off” means to, at a minimum, turn the Power off at the Case Molded Switch Handle at the front of the drive. Be Aware that unless the drive is disconnected at the utility the top of the Case Molded Switch will still be energized. Due to this fact it is highly recommended to disconnect the power at the utility.
❷	5	CAUTION: Only properly rated test equipment shall be used when taking any electrical measurements. Using an Ohm meter verify the Main Line fuse has continuity.
❸	5	See to the section Semiconductor Testing Procedure for Details on performing Electrical Checks on SCRs
❹	5	The Term “Power On” means to restore incoming Power to the VSD.
❺	5	CAUTION: Only properly rated test equipment shall be used when taking any electrical measurements. CAUTION: Proper PPE shall be worn at all times when repairing a VSD or electrical measurements are being taken.
❻	6	CAUTION: Proper Electrical PPE and appropriate electrical safety boundaries shall be adhered to when operating the VSD with the main doors open In addition to energizing the Main Power to the VSD, also start the VSD.
❼	6	Reverse the process in operational step 6.
❽	6	CAUTION: Prior to performing a mechanical/visual inspection or removing any sub-components from the VSD, proper lock-out/tag-out procedures shall be adhered too. Exchange the position of the CSB that did not have the LEDs illuminated on the System Control Board with another CSB that was functioning properly.
❾	6	The alternate CSB is the CSB that was switched with the “bad” CSB in operational step 8.
❿	6	See Operational Manuals for details.
⓫	6	If the CSBs are switched and the non-lit LED did not follow the first CSB nor did it manifest on the alternate CSB it means that likely a variable outside of the CSB or the SCB is the likely cause.

Load Faults

When an IOT condition is created due to a sudden voltage surge resulting from a short to ground or a short between phases in the Motor, the down-hole cable, the Wellhead penetrator, the Surface Cable or the Step-up Transformer on the output of the VSD this is referred to as a Load Fault.

Since the Load Fault is associated with a fixed phase or location on the output of the VSD, the IOT condition will manifest in a consistent pattern in relation to the phase indicated on the fault code displayed on the GD. There are specific situations where the pattern is "mostly consistent". That situation is explained below.

It would seem if there is a problem with the load connected between phase A and phase B on the output of the drive, an IOT would always appear on these phases in the drive. Unfortunately, that is not always the case. This is especially true with some arcing faults and occurs because there is an element of time involved as well due to cable and transformer inductance. Sometimes the actual fault may be delayed in time and due to this, the fault may appear to move from phase to phase. However, if you note the pattern, it will normally tend to show up in a predominant pattern (A-B, A-B, A-B, A-C, A-B, etc.). In the pattern described, all the occurrences were in A-B, with one in A-C. In these cases it can be helpful to rotate the output cables to the drive (A moves to B, B moves to C, and C moves to A) to see if the problem follows the cables. Remember: even if the fault is secure between A and B phases, it might show up on either the positive or the negative cycle. This means any pair of four LEDs could turn on to indicate only one problem.

The troubleshooting flow chart assumes that a consistent pattern has been identified.

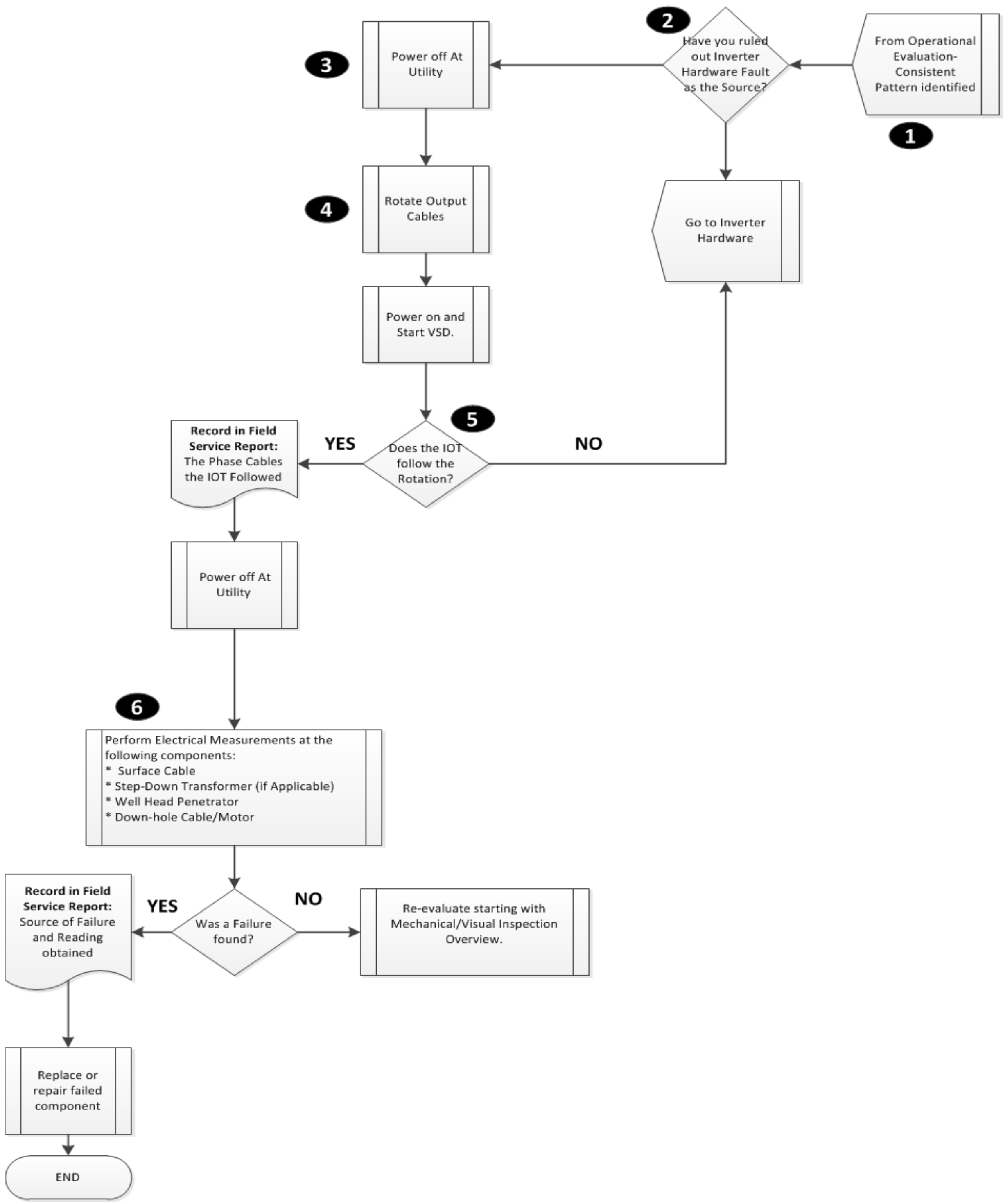


Figure 7: Load Fault- Electrical Evaluation

Table 4 -Detailed Description Load Fault-Electrical Evaluation

Operational Step Number	Figure Reference	Detailed Description
❶	7	Ensure that the IOT condition is repeating in the same phase or group of phases in a “mostly” consistent manner. For further operational definition of mostly consistent see introduction paragraph.
❷	7	For a Consistent Pattern Scenario, always investigate for Inverter Hardware Faults first.
❸	7	**CAUTION:** Prior to performing a mechanical/visual inspection or removing any sub-components from the VSD, proper lock-out/tag-out procedures shall be adhered too. To remove power at the utility is to remove disconnect power upstream from the Variable Speed Drive so that no power is at the input of the Case Molded Switch on the VSD.
❹	7	Rotating cables (A to B, B to C, C to A) will maintain pump rotation but change the relation between the VSD phase and motor phase.
❺	7	If the IOT does not follow the rotation, then it is reasonable to deduce that the fault exists somewhere in the VSD, not with the load.
❻	7	**CAUTION:** Prior to performing a mechanical/visual inspection or removing any sub-components from the VSD, proper lock-out/tag-out procedures shall be adhered too. Procedures for electrically testing the Surface Cable, penetrator and Down-hole cable can be found in document FAL-ESPS-S008-25GO-07-001: Fault Find-ESP Systems. The same procedures as outlined in the above mentioned document can be adapted to testing the primary windings and secondary winding of a step up transformer.

Inverter Hardware Faults

IOT conditions relating to the Inverter Hardware will normally manifest in a consistent pattern in relation to the phase indicated on the fault code displayed on the GDI. The first two flow charts are related to evaluating IOTs that have the outward symptomology of the Power LED out or the signal LED out on an ISB. It is important to note that the phase associated with the IOT shown on the GDI may not coincide with the phase of the malfunctioning ISB. The reason is that the effect of a malfunctioning ISB is integrally connected to the switching behavior of the entire inverter section. The third flow chart shows how to verify the IOT condition threshold by utilizing the Short Circuit Test. If by following these flow charts the source of the IOT cannot be identified and all signs are pointing towards the Inverter Hardware Section as the most likely area of interest then begin rechecking the connection points following the guidelines in Appendix D.

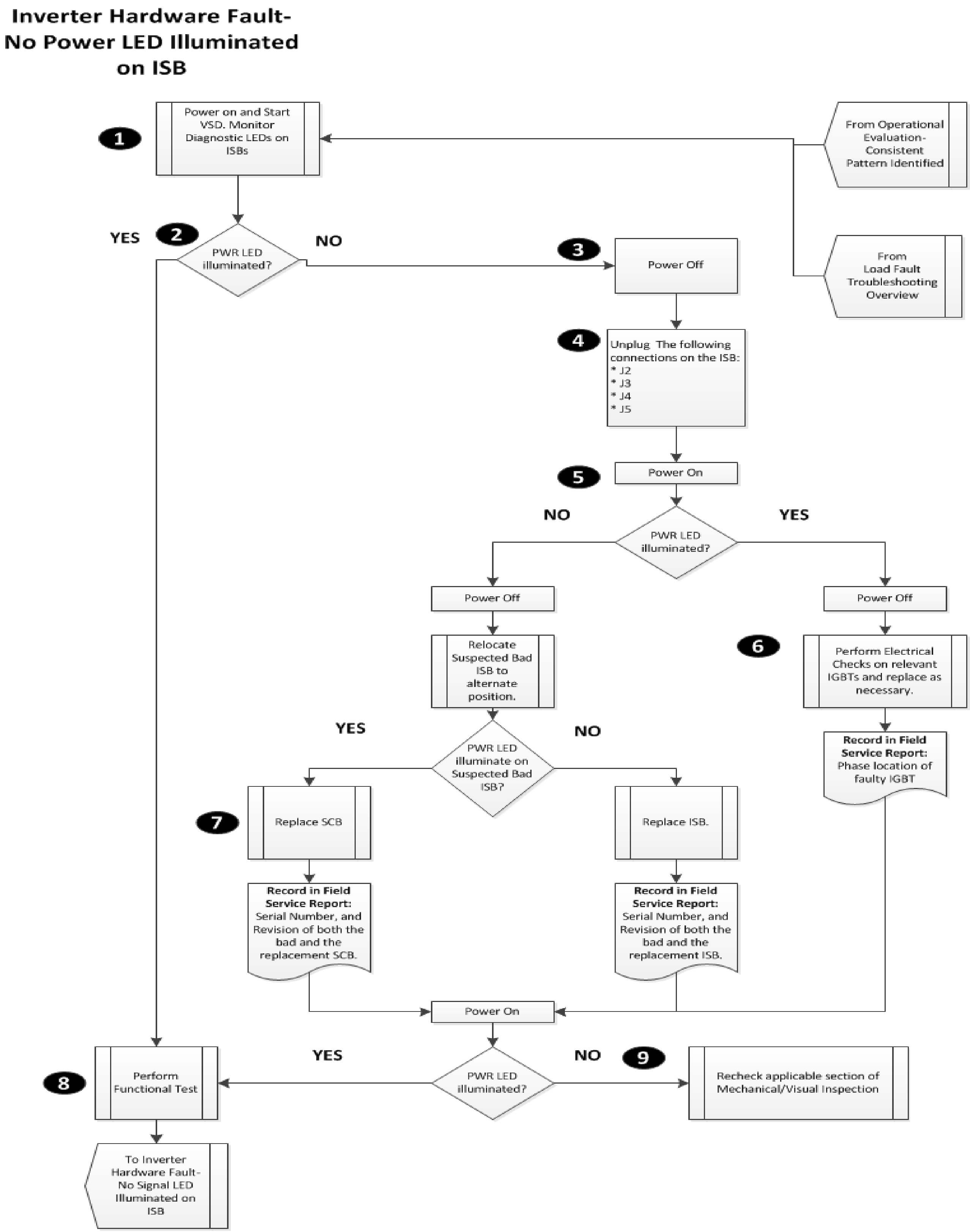


Figure 8: Inverter Hardware Fault- No Power LED Illuminated on ISB

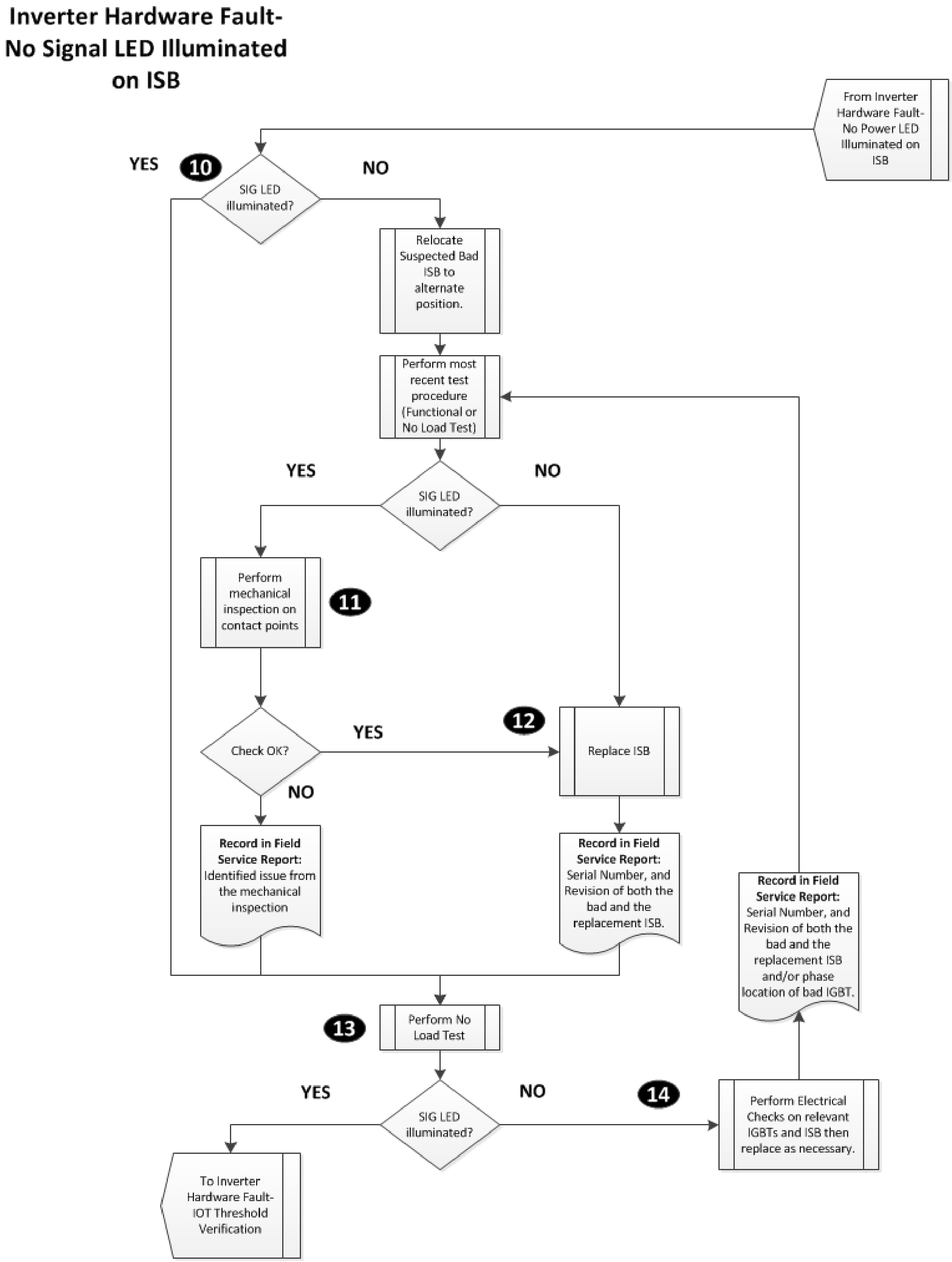


Figure 9: Inverter Hardware Fault- No Signal LED Illuminated on ISB

Inverter Hardware Fault-
IOT Threshold Verification

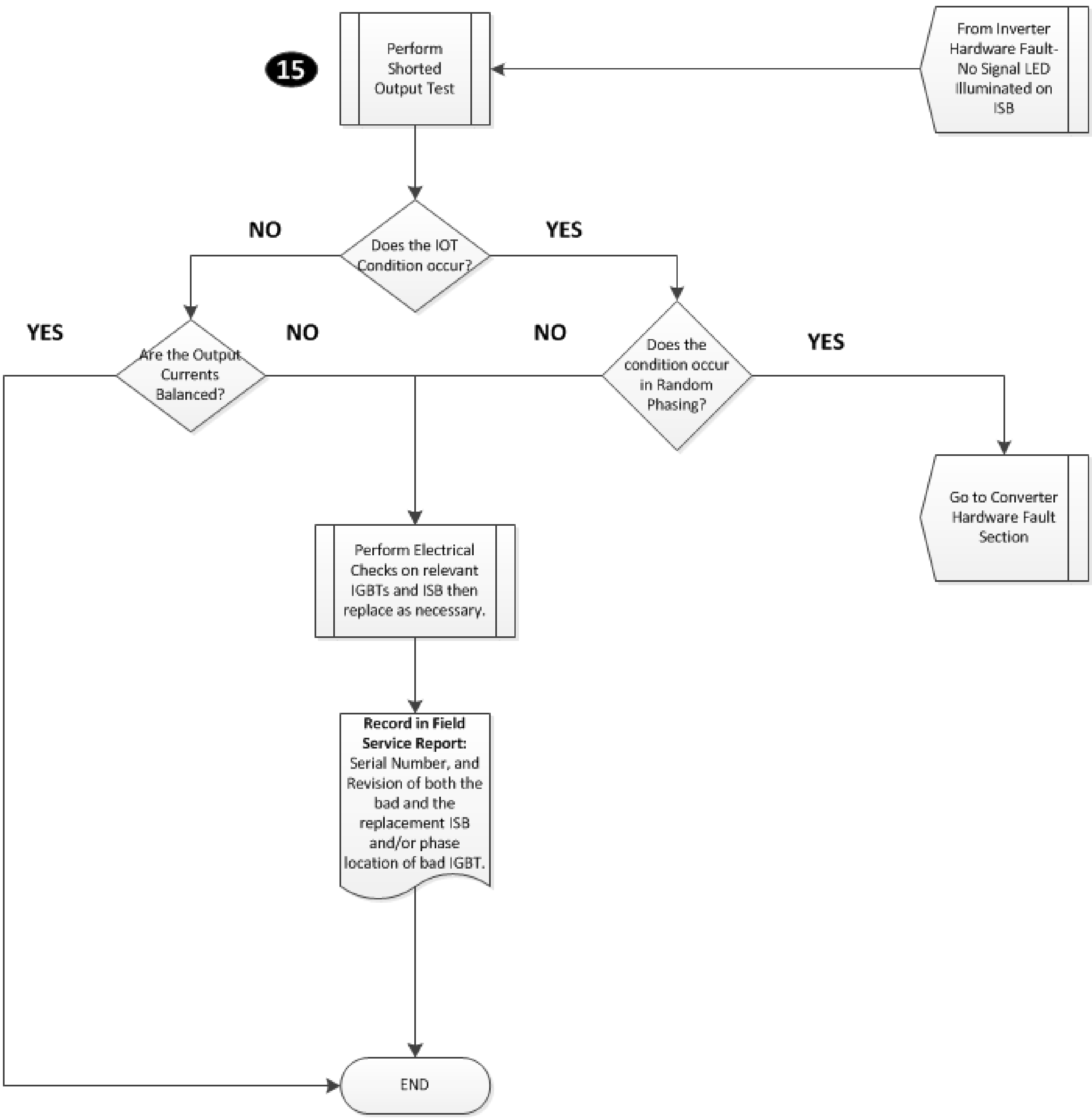


Figure 10: Inverter Hardware Fault- IOT Threshold Verification

Table 5- Inverter Hardware Fault Detailed Descriptions

Operational Step Number	Figure Reference	Detailed Description
❶	8	**CAUTION:** Proper Electrical PPE and appropriate electrical safety boundaries shall be adhered to when operating the VSD with the main doors open In addition to energizing the Main Power to the VSD, also start the VSD.
❷	8	See the section Inverter Signal Board LED Indicator Operation for detailed discussion.
❸	8	**CAUTION:** Prior to performing a mechanical/visual inspection or removing any sub-components from the VSD, proper lock-out/tag-out procedures shall be adhered too. The Term "Power Off" means to, **at a minimum,** turn the Power off at the Case Molded Switch Handle at the front of the drive**. Be Aware that unless the drive is disconnected at the utility the top of the Case Molded Switch will still be energized.** Due to this fact it is highly recommended to disconnect the power at the utility.
❹	8	By disconnecting J2-J5 on the ISB, the associated IGBT modules are being isolated from the ISB.
❺	8	The Term "Power On" means to restore incoming Power to the VSD.
❻	8	Refer to the section Semiconductor Testing Procedure for detailed discussion on how to perform electrical checks on the IGBTs.
❼	8	The assumption made here is that the loss of the Power LED is associated with the circuitry on the SCB instead of the ISB itself. Prior to replacing the SCB it is a recommended best practice to double check to ensure the connection points between the SCB and ISB are free of residue (use contact cleaner) and that the ISB was properly seated.
❽	8	Detailed instruction for the Functional Test is included in the relevant VSD Troubleshooting and applications manuals. • Part Number 901707: GCS Troubleshooting and Applications Manual • Part Number 907141: Electrospeed Advantage Drive Troubleshooting Manual

Operational Step Number	Figure Reference	Detailed Description
❾	8	If the Power LED does not illuminate after replacing the ISB and/or SCB then re-evaluate previous steps.
❿	9	See the section Inverter Signal Board LED Indicator Operation for detailed discussion of the Inverter Signal Board Diagnostic LEDs.
⓫	9	The relocation of the ISB was a secondary verification method of the fault. A lost Signal LED is indicative of a damaged or failed ISB board. If the LED comes on by relocating, this is an uncharacteristic result. Best Practice is to find out why it came back on.
⓬	9	If the reason why the ISB began to work again cannot be identified, then it is a best practice to replace it.
⓭	9	Detailed instruction for the No Load Test is included in the relevant VSD Troubleshooting and applications manuals. • Part Number 901707: GCS Troubleshooting and Applications Manual • Part Number 907141: Electrospeed Advantage Drive Troubleshooting Manual
⓮	9	Refer to the section Semiconductor Testing Procedure for detailed discussion on how to perform electrical checks on the IGBTs. Refer to the section Inverter Signal Board Testing Procedure for a detailed discussion on how to perform electrical checks on the ISB.
⓯	10	Detailed instruction for the Shorted Output Test is included in the relevant VSD Troubleshooting and applications manuals. • Part Number 901707: GCS Troubleshooting and Applications Manual • Part Number 907141: Electrospeed Advantage Drive Troubleshooting Manual

Table 6: List of IOT Event Codes or Displayed Alarms

	Source of IOT			
	Incoming Power Fault	**Converter Hardware Fault**	**Inverter Hardware Fault**	**Load Fault**
Event or Displayed Alarm	0-XING	0-XING	IOT	IOT
	Converter fault	Converter fault	Overcurrent	Overcurrent
	Ride Thru Low Speed Fault	Ride Thru Low Speed Fault	UPF 0	UPF 0
	SAG	SAG		

Event or Displayed Alarm codes not listed in the table above are not generally considered indicators of an IOT condition.

Mechanical/Visual Inspection

Input/Output Field Wire Connections and Main Internal Power Connections
(excerpt from CTB09-006)

Necessary Tools

A. Calibrated torque wrench that reads inch-pounds or Newton-meters.
B. Applicable size socket for fastener. (See Table 6 below)

Table 7- Socket Sizing / Torque Table for Power Connections

Baker Hughes P/N	Description	Torque Value IN-LBS (N-m)
C901455	PDB; 3/8" DIA STUD; LENGTH 5"	228 (26)
C901454	PDB; 1/2" DIA STUD; LENGTH 7 5/8"	496 (56)
C900879	M8 screw, 25mm long, HEX head	252 (28)
C58869	M8 screw, 20mm long, HEX-PHILLIPS (cross-tip) head	140 (15)
VARIOUS	Case Molded Switch	Marked on Front of Switch

Procedure

WARNING: DO NOT PERFORM THE FOLLOWING INSPECTION UNLESS PRIMARY POWER IS REMOVED AT THE SOURCE.

A. Adjust torque wrench to applicable setting as defined in Torque Specification Table on Table 8.
B. Turn torque wrench until click is heard. This indicates the wrench has reached the set torque value. Do not turn the torque wrench beyond click; excessive torque could create undo strain on the fastener resulting in failure.
C. Repeat Steps A and B until all torque points as defined in this Technical Brief are checked.

Torque Points

The two types of connections that have torque points that must be verified are:

A. Input/Output Field Connections; and
B. Main Internal Power Connections

Input/Output Field Wire Connections

Input/Output Field Wire Connections are defined as the point on the drive where the external power source is connected to the input of the drive and the junction point where the output of the drive is available for interface with the external equipment. Two types of terminals exist for the Input/Output Field Wire Connections on the standard GCS drive; Power Distribution Blocks (PDB) and Bus Bars.

Located near each Input/Output Field Wire Connection is a label with torque values, as well as other pertinent information concerning the field connections. This label was updated in 2009 with new torque values for the C901454 PDB and the M8 bolt provided with the drive for the field connections (C900879). The Centrilift P/N for the updated label is C905570, and it is presented in Figure 11.

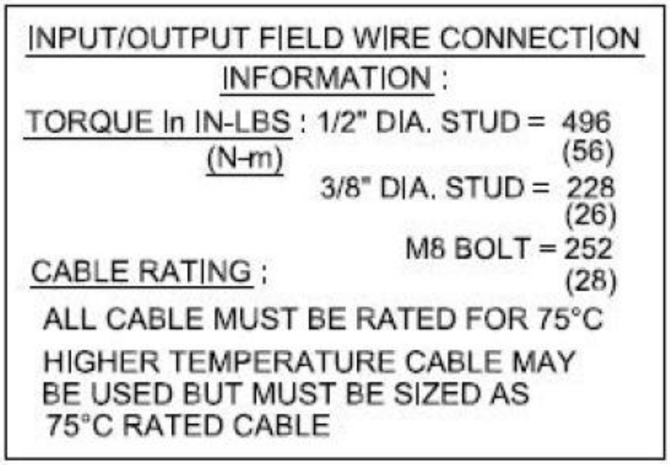


Figure 11: New Label P/N C905570 replaces labels C901923, C901924, and C901925 on all models of GCS drives.

The input / output field wire connection label contains new values for torqueing of the C901454 PDB and the M8 bolt used for field connections on the input/output bus bars.

Power Distribution Blocks

Figure 12 shows the Torque points on the Power Distribution Blocks. Follow instructions in the section titled **Procedure** to check each point identified by the white arrows below.

Figure 12: Shown is an input J-box for a 24P 8N4 without the customer connections

All the nuts pointed out by the white arrows are torque points to be checked.

Even though a 24P 8N4 is shown, the same torque points on the PDBs are valid on all series of GCS drives that use them.

Power Distribution Block Identification

Two different sizes of PDBs are used in GCS drives: C901454 and C901455. When mounted, it can be difficult to tell the difference. Figure 13 shows both PDBs along with two of their defining dimensions; the length of the block and the diameter of the stud.

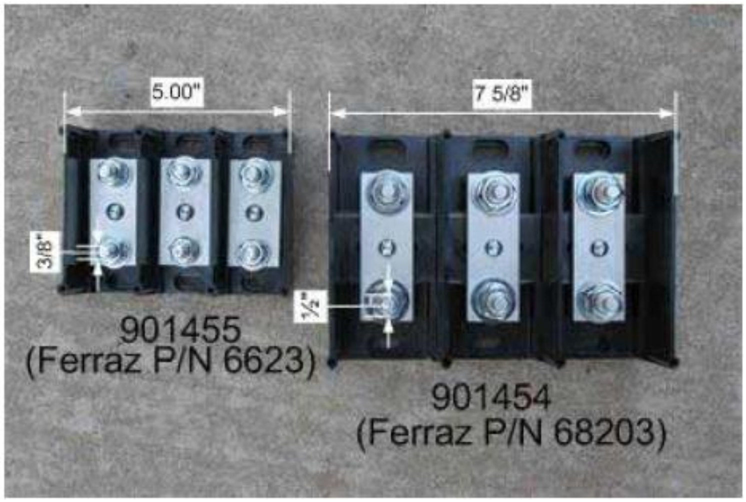


Figure 13: C901454 is the larger of the two blocks with a length of 7 5/8" and a stud diameter of 1/2".

When the PDBs are not mounted, they can be identified by their manufacturer's label located on the side of the block. The manufacturer's number for each of the Centrilift part numbers are identified in parenthesis in Figure 13. Figure 14 is a photograph of the manufacturer's label.

Figure 14: The manufacturer P/N of the Centrilift PDB C901454 is the number 68203.

The label shown is on the side of the block

Bus Bars
Figure 15 is a photograph of a typical bus bar application in a GCS drive.

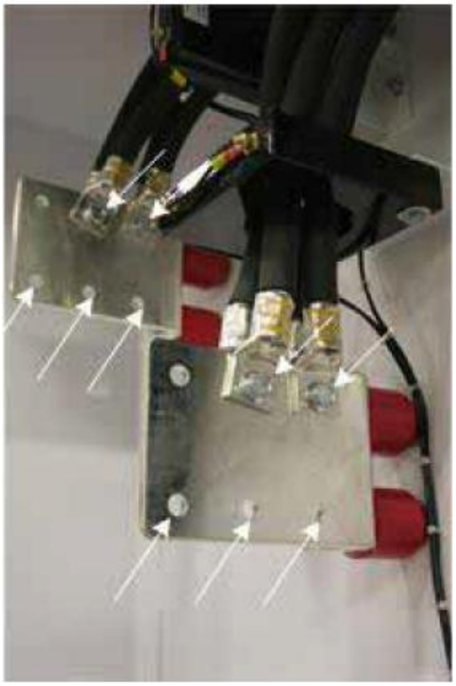


Figure 15: Typical bus bar application in a GCS drive without the customer connected cables.

The bolts provided with the bus bars for the customer connections and the factory installed cables are M8x1.25mmx25mm long (Centrilift P/N C900879). At the points indicated with white arrows above, follow instructions in this **Mechanical/Visual Inspection** section titled **Procedure**.

Main Internal Power Connections

Main Internal Power Connection include the input power cable connections for the switch to the converter section on the planar bus bar, and the output cable connections from the inverter section on the planar bus bar to the Input/Output Field Wire Connections. Figure 6 is a photograph showing the locations of each torque point in an 8N4 drive. The other models will vary in number but not in general location of torque points. The torque points are shown by the white arrows.

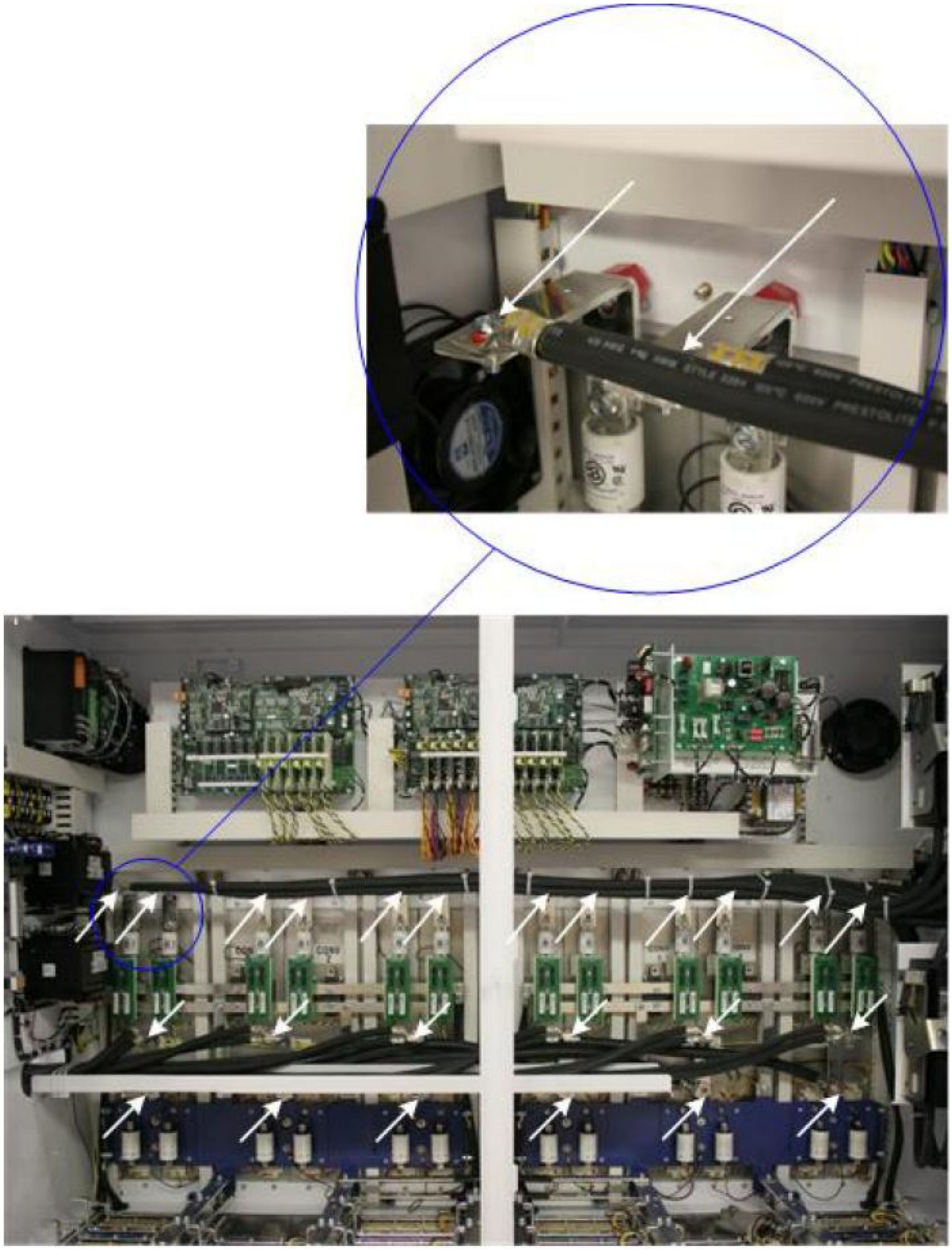


Figure 16: A picture of the inside of an 8N4 drive.

Each white arrow indicates a location of a torque checkpoint. Two different 8 millimeter screws are used for these connections, one is 20mm and the other is 25mm long. THESE TWO SCREWS HAVE DIFFERENT TORQUE VALUES. Two different screws are used in the torque points shown above. Both are 8 millimeter, but one is 20mm long and the other is 25mm long. The 20mm screw and the 25mm screw have different torque values. The 20mm screw (Centrilift P/N C58869) has a Phillips slot in the head (See Figure 17).

Figure 17: This photo shows the 20mm long, 8mm screw (Centrilift P/N C58869) used in some of the main internal power connections.
This screw has a lower torque value than that of the 25mm long screw (Centrilift P/N C900879).

Table 8: Torque Specification - Input/Output Field Wire & Main Internal Power Connections

Centrilift P/N	Description	Torque Values IN-LBS (N-m)
C901455 (66263)	PDB; 3/8" DIA. STUD; LENGTH 5"	228 (26)
C901454 (68203)	PDB; 1/2" DIA. STUD; LENGTH 7 5/8"	496 (56)
C900879	M8 screw, 25mm long, HEX head	252 (28)
C58869	M8 screw, 20mm long, HEX-PHILLIPS head	140 (15)
VARIOUS	Case Molded Switch	Marked on Front of Switch

All other electrical connections

Connections with no defined torque values include the following:

A. Structural Connections; and
B. Any electrical connection not previously described in this document.

For the above two categories, judiciously applied torque via standard hand tools (screwdrivers, ratchet and sockets, and wrenches/spanners) as used in the field service environment have historically proven to be sufficient for purpose.-In situations where hand tools are used, all connections must be tightened to the point where locking mechanisms such as lock and star washers are fully compressed and all electrical connections are secured from moving by physical inspection.

Power connections internal to VSD

- Using a torque wrench, properly torque the input cable connections at top of Input switch(es). Torque values are shown on a label which is located on the switch itself.
- Check tightness of the hardware for the fuses, top and bottom
- Remove Snubber boards to access the standoffs (there are 3 standoffs per SCR), check the tightness of the standoffs to the SCRs
- Check the tightness of the remaining hardware connections to SCRs and Diode(s)
- Check the tightness of the cable connection where link reactor meets the Converter section positive bus bar
- Check the tightness of the cable connection where link reactor meets the Inverter section, positive terminal of Planar bus bar system
- Check the tightness of the hardware which connects the horizontal bus bars between Planar bus bar system and DC bus capacitor modules
- Check the tightness of the hardware which connects the Negative DC bus between Converter and Inverter sections
- Remove Auxiliary DC bus capacitors to access the standoffs (2 standoffs per Auxiliary capacitor), check the tightness of the standoffs to the IGBTs
- Check the tightness of the remaining hardware connections between Planar bus bar system and IGBTs
- Check tightness of all screws of the DC bus capacitor modules

PWM Filter section (if applicable)

- Check the tightness of the PWM Filter Inductor cable connections in Junction box section
- Check the tightness of the PWM Filter Inductor cable connections in PWM filter enclosure
- Check the tightness of the hardware for the PWM filter fuses
- Check the tightness of the bus bar to filter contactor connections at contactor terminals
- Check the tightness of the filter capacitor connections to bus bars
- Check for tightness all connections on filter capacitors

Electrical connections—low current

Note: “Pull test” is a check of the crimp connections. Hold firmly to the crimped-on terminal while pulling on the wire. If wire disconnects from the terminal the pull test failed, and terminal must be replaced.

- Ensure tightness of connections between bus bars of input fuses and Switching Supply Board (SSB) of GCS VSD or Basic Power Supply Board (BPSB) of Advantage VSD, plus all other similar connections such as those to Control Power Transformers (CPTs) and heatsink cooling fan motors.
- Perform pull test of gate leads to SCRs

- If the VSD is 12-pulse or 24-pulse it will be equipped with Current Transformers (CTs) around two or more input cables. Perform pull test of wires connected to X1 and X2 terminals of CTs.
- Visual inspection of SCR gate lead connections to Converter Signals Boards (CSBs). Consult the section **Molex Connector Maintenance Instructions** Perform pull test of connections from DC bus capacitors to bleeder resistors
- Perform pull test and check for tightness of gate leads to IGBTs
- Perform pull test and check for tightness the wire connections of Output CTs
- Visual inspection of IGBT gate lead connections to Inverter Signals Boards (ISBs). Consult the section **Molex Connector Maintenance Instructions**
- Visual inspection of remaining Molex connections to SCB or BSCB. Consult the section **Molex Connector Maintenance Instructions** for more information.

Inverter Signal Board LED Indicator Operation

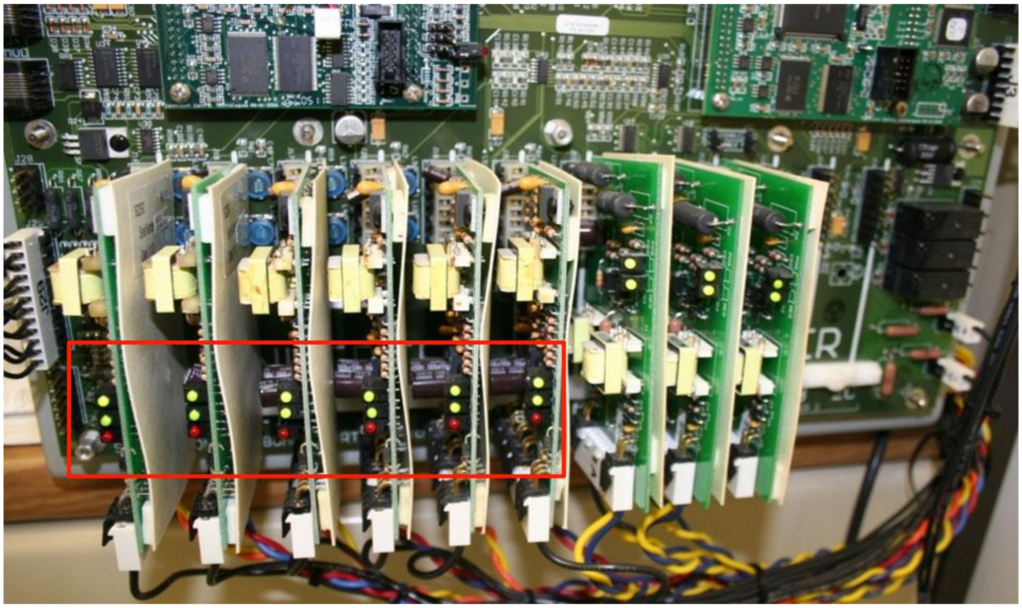


Figure 18: Inverter Signal Boards Installed.

The Red Box shows where the LED Indicator lights are located when viewing the ISBs with the main door open. CAUTION- Proper Electrical PPE and appropriate electrical safety boundaries shall be adhered to when operating

Figure 19: Diagram of the LEDs on the ISB. LED 1 is the Signal LED; LED 2 is the Power LED and LED is the Fault LED

1) The Signal LED is marked as "SIG" on the ISB. When illuminated, this LED indicates that the ISB is sending firing signals to the IGBTs. At frequencies lower than 15 Hz the LED will appear to blink. At frequencies greater 30 Hz the LED will appear to be steady on.
2) The Power LED is marked as "PWR" on the ISB. When illuminated, this LED indicates that the ISB is energized.
3) The Fault LED is marked as "FLT" on the ISB. This LED will illuminate when an IOT condition has occurred. NOTE: The IOT LED will not stay on continuously once tripped but will illuminate for a short duration after the IOT occurs.

Molex Connector Maintenance Instructions

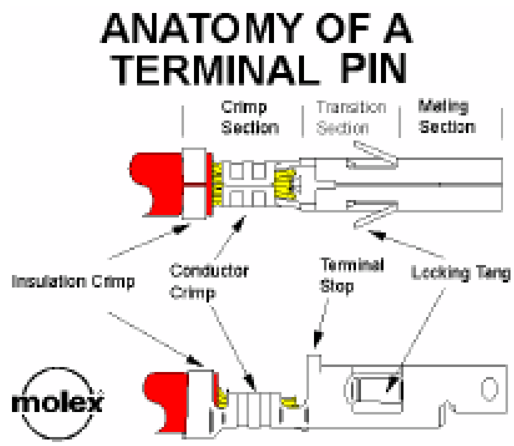
Much of the wiring in Centrilift ICS and GCS drives is done with push-on connector blocks at the PC boards. In Claremore the name associated with the parts involved is the name of the manufacturer, Molex. The pins (Molex terminals) that are crimped to 18 AWG wire are gold plated for reliability. After crimping the terminal to the wire, the terminal is inserted into one of the slots in a white plastic housing (connector). In certain cases not all the slots in the connectors are used for wire, some of the slots may contain a white plastic blocking key which lines up with an empty terminal in the board connection. This helps prevent misalignment of the connectors.

Important Information for proper Crimping

It is important to be careful when crimping the Molex terminals onto the 18 Awg wire. To begin with, it helps to understand that a terminal has three major sections: Mating, Transition and Crimping. (Note that the mating section in our connectors is slightly different from shown.)

The Mating section, as the name implies, is the section of the terminal that mates, or becomes the interface, with the other half of the connection. Anything that you do that deforms the Mating Section, especially during the crimping process, will only reduce the connector's performance.

The Transition Section also is designed so that it would not be affected by the crimping process. Here again, anything you do that changes the position of the Locking Tangs or Terminal Stop affects the connector's performance.



The Crimp Section is the only section that the crimping process is designed to affect. Using termination equipment recommended by the connector manufacturer, the crimp section is deformed so it can be securely attached to a wire. Ideally, all the work that you do to crimp a terminal onto a wire occurs only in the Crimp Section.

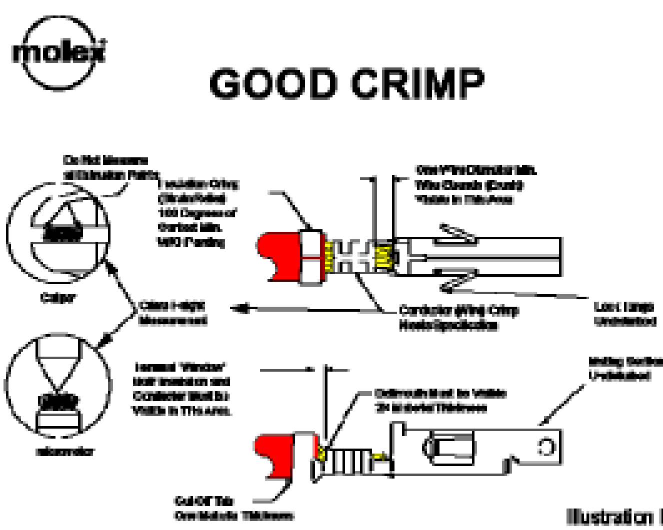


Illustration B.

An example of a properly performed crimp is seen here. The insulation crimp compresses the insulation without piercing. The wire strands (or brush) protrude through the front of the conductor crimp section by at least the diameter of the wire's conductor. For example, an 18 AWG wire would protrude at least .040". Both the insulation and conductor are visible in the area between the insulation and the conductor Crimp Section. The conductor Crimp Section shows a bellmouth shape in the leading and trailing ends, while the Transition and Mating Sections remain exactly the same as they were before the crimping process.

Stripping the right amount of insulation from the wire:

For optimal results, **1/8" (3 mm) to 5/32" (4 mm)** of insulation should be stripped at the end of the wire.

- If the insulation is not stripped back enough, the *Conductor crimp* may trap insulation resulting in an intermittent connection with the conductor.
- If the insulation is stripped back too much, the *Insulation crimp* may not grab the insulation and thus the 'strain relief' component of the connection is lost and the wire tends to break off from the connector and then short out.

Established Part Numbers – Connectors & Crimpers

The table below shows part numbers and descriptions of all the "Molex" parts used in the ICS and/or GCS product lines. Also shown are Centrilift part numbers for the crimp tools necessary for making high quality, reliable crimps of the terminals to the wire. Two numbers are listed, one for a "U.S version" and the other for a "European version". The manufacturer's part number of each crimper is given in the Product Description column as it may be desirable to purchase from a local supplier.

Part Number	Product Description	Notes
47740	CONN HSG 2 CKT 7A W/18AWG	2 pin Molex connector
47957	CONN HSG 3 CKT 7A W/18AWG	3 pin Molex connector
47739	CONN HSG 4 CKT 7A W/18AWG	4 pin Molex connector
47742	CONN HSG 5 CKT 7A W/18AWG	5 pin Molex connector
47959	CONN HSG 6 CKT 7A W/18AWG	6 pin Molex connector
47743	CONN HSG 8 CKT 7A W/18AWG	8 pin Molex connector
900475	CONN HSG 11 CKT 7A W/18AWG	11 pin Molex connector
900133	CONN HSG 12 CKT 7A W/18AWG	12 pin Molex connector
900134	CONN HSG 13 CKT 7A W/18AWG	13 pin Molex connector
901621	CONN HSG 14 CKT 7A W/18AWG	14 pin Molex connector
47803	CONN HSG 20 CKT 7A W/18AWG	20 pin Molex connector
47741	PIN CONN CRIMP TERM 18-24AWG	Molex terminal
47958	CONN KEY PLZN	Blocking key
902998	MOLEX HTR2445A Crimp Tool	U.S. version
902999	MOLEX 69008-0953 Crimp Tool	European version

Using a Multi-meter to check connector signals:

Many problems can be traced to poor connections on the "board-end" of the gate lead wiring harness, where the harness connects to the (Converter or Inverter) Signals boards. The terminals on this end of the wires are constructed like a spring, and it's the spring tension that creates and maintains the contact between the terminal and the male pin. We've seen many cases of the Molex terminals being mashed down far enough that they won't spring back, causing a poor or nonexistent contact. At the right is a photo showing two Molex terminals outside the plastic housing. The one on the left has been mashed by a meter lead, the one on the right has not. The difference between the two could be the difference between a drive that runs correctly and a drive that gives you unexpected problems!

The following cannot be overstated: Be careful with your meter leads. Most field personnel use Fluke 87 meters in the field, and the leads that come with the meter have odd shaped tips. Quite often it becomes necessary to check continuity of a wire and in doing so will shove the meter lead into the Molex connector. This compresses the terminal too much and often ruins the connection. This problem has been around for a long time, but with ICS we used far fewer of this type terminal than we do in GCS. The possibility of these terminals causing problems for you is therefore higher in the GCS drives than it would be in ICS.

Caution:

DO NOT insert meter leads into the socket side of the Molex connector as you could bend the spring clamp in the connector resulting in an intermittent connection with the ISB after the test.

Do use the small access cut-outs on the side of the moles connector as shown to the right.

In the ICS we used these terminals at the low voltage DC power supply connections almost exclusively. So it was fairly easy to troubleshoot a poor connection—either the board had a constant power supply or it didn't. In GCS however, we use these terminals at both the Inverter and Converter Signals boards along with the power supplies. Since many of the GCS models have two or more SCR's in parallel and four or more IGBT's in parallel, you may find a drive that has intermittent failures of these devices. This could be due to one device always pulling the load of two, or perhaps the second one only works intermittently. Either of these cases will cause failures—it's just a matter of time!

To determine the worth of the Molex connections: Look into the end of the white plastic connector and if you can see that the terminal doesn't completely fill the slot, depress the locking tab on the back side with a small screwdriver, push the Molex connection out of the housing and repair or replace the terminal. Also examine the crimps to ensure that the insulation has not been crimped in the *conductor crimp*.

There are three steps to repairing the terminal.

1. Bend the terminal out far enough so that it will make contact with the post.
2. Bend the spring back into position so that the terminal can maintain good contact over the life of the connection.
3. Ensure that the little locking device on the back side is protruding far enough to lock the terminal into the plastic connector so you don't force the crimped insert out of the connector housing when you plug into the board.

Semiconductor Testing Procedure

Testing SCR and IGBT Power Components V 1.4 Mar 10, 11

GCS Electrospeed Drives use the following power semiconductor devices:

- Silicon Controlled Rectifiers (SCR's) on the input (Converter) section.
- Diodes (Freewheeling Diodes)
- Isolated Gate Bipolar Transistors (IGBT's) on the output (Inverter) section.

Remember Mickey's rule of thumb when testing power devices:

"You cannot prove that a power semiconductor is good with an ohmmeter. You can only prove that it is bad."

If you see a device shorted, it is definitely bad. If you see unusual readings, it might be bad. However, if you see good readings you can only say that it might be (or probably is) good. You can only tell for sure by substitution.

Matching Devices to Prevent Problems

Power semiconductors are purchased from different manufacturers (alternate sourcing). Though parts from different manufacturers are functionally compatible, they may behave slightly different under load. For this reason, it is best to ensure that parallel components are from the same vendor. This also applies when changing one or more damaged components. The following rules apply:

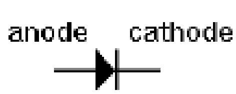
1. Though not imperative, it is generally recommended to match (from the same manufacturer) if possible:
    a. SCR modules connected to each input phase
    b. Freewheeling Diode Modules
2. Matching IGBTs is more critical. It is important to replace all devices in parallel even if they are not physically close to each other. Consider an 8000 series drive where the total current is significantly more than the rating of any one device. In that case, it would be best to replace IGBTs in groups of 4. (All 4 positive devices in a phase or all 4 negative devices).

Testing Freewheeling Diodes

Tools Required: Digital Multimeter with diode check.

The freewheeling diodes do not fail very often. The primary symptom of a failed diode is a fuse failure immediately after a start attempt. (Diode shorted causing a short from positive to negative bus)

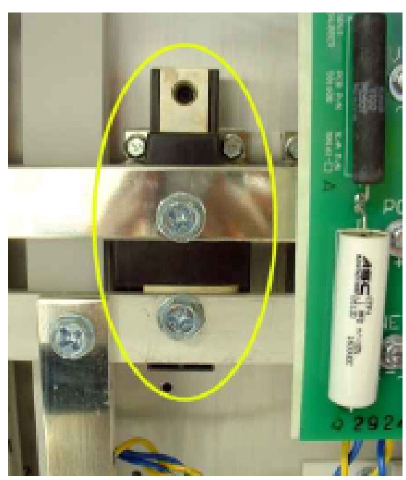
Electronic Symbol for a Diode



Test Procedure:

1. If the part is installed, check for a short by measuring resistance across the + to – DC bus bars. If no fault detected, isolate the device from the bus bars.
2. Set the meter to 'diode test' mode
3. Use the diode test across the part
4. Test should show a normal diode. Infinite impedance in one direction, ~ .6 volts in the opposite direction.

Picture of a Diode from a 4N3



Testing SCR's

Tools required: Digital Multimeter,
500 – 1kV megger. (Optional for dielectric tests)

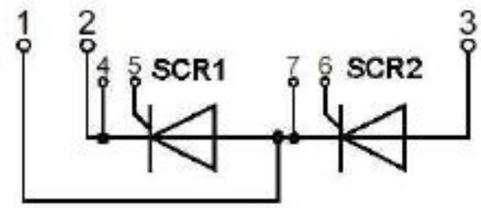
Basic electronic diagram for an SCR

A = Anode

K = Cathode

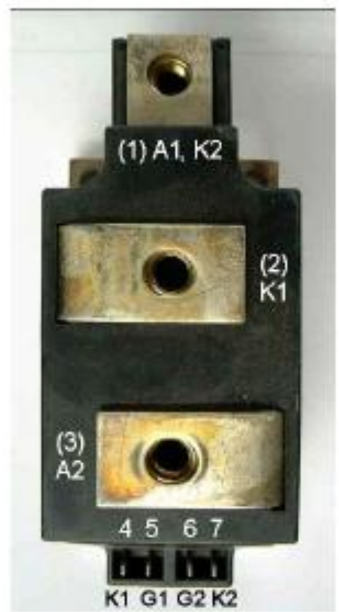
G = Gate

Diagram that appears on the SCR modules



Note that the modules we use have **TWO** SCR's in one package, so it is important to test both SCR's in the module.

250 Amp SCR Module



Test Procedure:

1. If the SCR's to be tested are installed in a drive, the modules must be isolated from other devices:

- Remove any bus bars connected to the A & K terminals.
- Remove the Gate lead connections that run to the CSB's

2. Check for Shorts / low impedances

- Set meter to ohms Scale
- Check A – G connection, should be > 500 K ohms both directions.
- Check A – K, should be > 500 K ohms both directions.
- Check G – K, should be 5-40 ohms both directions. (Optionally use the 'Diode test' meter setting to test the G-K connection, should see 5-30 mV)

3. Check for insulation breakdown (A-K junctions & ground).

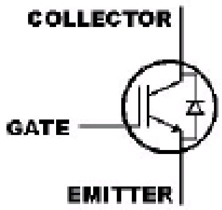
In cases where nuisance IOT's are evident it may be that the SCR module is not completely shorted, but may have internal damage. Using a megger we can test the insulation in the device:

- Set a megger to 500 V or 1KV
- Check the Anode to Cathode junction of both SCR's in both directions.
    - Junctions should read 50 Meg ohms or greater, typically 500-1000 meg ohms.
    - A part with weakened dielectric strength will be easily identified in the range from 1-5 Meg ohms.
- Finally meg between all large A and K terminals and the base of the device (earth ground) again in both directions.

Testing IGBT's

Tools Required: Digital Multimeter, with diode check.

Basic electronic diagram for an IGBT

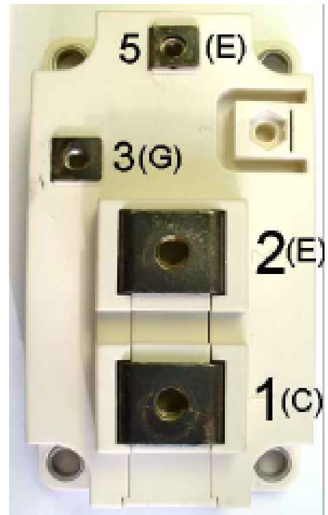


C = Collector

G = Gate

E = Emitter

Typical IGBT module:



NOTE: An Inverter Signals Board with an LED that is not lit can indicate a problem in the IGBT Gate drive circuit, potentially caused by a damaged Gate to Emitter junction.

The following procedure is split into two parts.

- The first half focuses on testing G – E which can be completed by simply removing the ISB connectors.
- The second half details tests for the C-E junction, which requires isolating the devices by removing the bus bars.

Caution:

DO NOT insert meter leads into the socket side of the Molex connector as you could bend the spring clamp in the connector resulting in an intermittent connection with the ISB after the test.

DO use the small access cut-outs on the side of the molex connector as shown to the right.

Test Procedure:

1. Test the G(ate) to E(mitter) junction
    a. Remove the Gate lead connections that run to the ISB's (Remove the connector from the ISB or disconnect terminals 3(Gate) and 5(Emitter)
    b. Set meter to ohms scale
    c. Check G – E both directions. The readings will look like a small capacitor. It should start with low ohms, and then build up until reaching Infinite. (In one case an IGBT was identified as bad when the meter reading was 900 k in one direction and fluctuating in the other)
    d. Set meter to diode scale
    e. Check the G-E junction both directions. This should read infinite in both directions. (In one case an IGBT was identified as bad when it read 300 mV in one direction)

2. Test the C(ollector) to E(mitter) junction
    a. Remove any bus bars connected to the C & E terminals.
    b. Set meter to ohms scale
    c. Check C – E both directions. Should be very high impedance one direction (> 800 kohms), infinite in the other.
    d. Set meter to Diode Test
    e. Test the diode across C - E terminals. Should read .3 to .5 volts one direction, infinite in the other.

Inverter Signal Board Testing Procedure

Position the ISB as shown below.

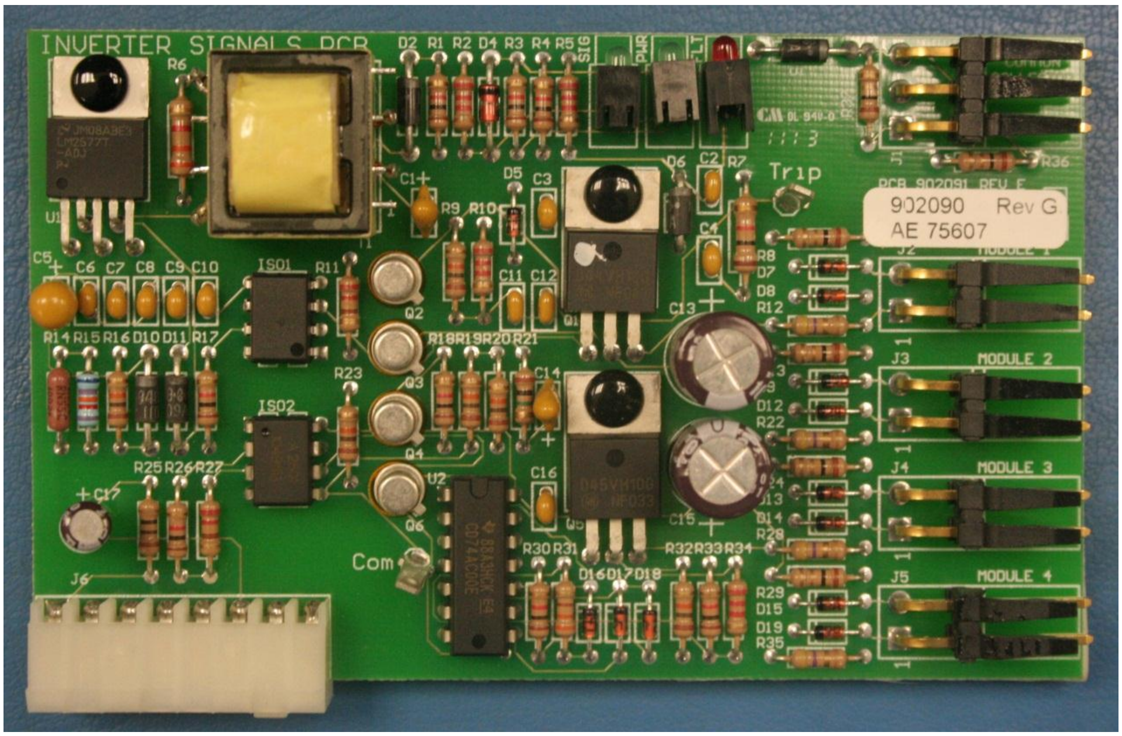


Figure 20: Orientation of ISB to locate Components to check

1) Locate the components to measure. At the bottom Right-hand corner you should find R35, near the two-wire connector J5. There is a straight line of resistors and diodes going up from this point, ending with R8, located near J2 (see figure below).

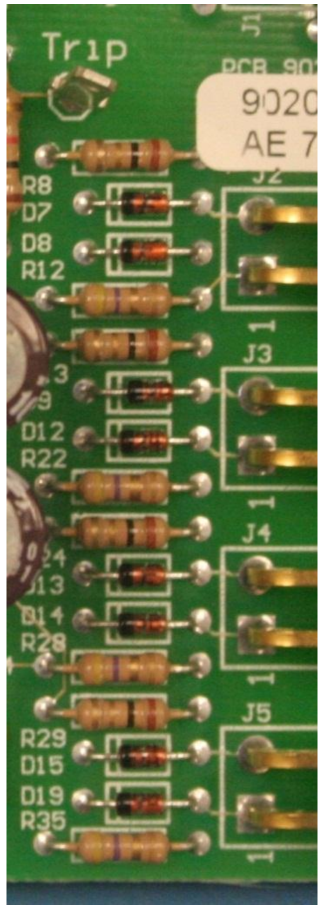


Figure 21- Resistors and Diodes to be checked on ISB.

2) Measure all the resistors shown in line above. Set the Ohmmeter on the low ohm scale. They should not read “open”.

3) Confirm that the diodes in line above are good. Set the meter on the diode scale. With the red lead to the anode and the black to the cathode, there should be a forward voltage drop of approximately 0.7 Volts. Reversing the leads should indicate an open circuit (OL)

Glossary of Terms and Definitions

IOT	Instantaneous Overcurrent Trip
Condition	Alarm Condition that inhibits the VSD from continuing to operate.
Inverter	A classification of a portion of the Variable Speed Drive functional topology related to the generation of the output power waveform. (DC-AC conversion).
Inverter Section	See Inverter
Inverter Hardware	The collective name given to the group of subcomponents that make up the inverter section which include: • IGBT • ISB • SCB • Wire Harness (IGBT to ISB)
Converter	A classification of a portion of the Variable Speed Drive Functional topology related to conditioning the input waveform for use by the inverter. (AC-DC conversion)
Converter Section	See Converter
Converter Hardware	The collective name given to the group of subcomponents that make up the converter section which include: • SCR • Diode • CSB • SCB • DC Bus Capacitors • Link Reactor • Wire Harness (SCR to SCB)
ISB	Inverter Signal Board
CSB	Converter Signal Board
SCB	Systems Control Board

IGBT	Insulated Gate Bipolar Transistor
SCR	Silicon Control Rectifier
Diode	Power Semi-conductor device used in conjunction with the SCRs to make up the Converter Section.
DC Bus Capacitors	Power Capacitors used in the DC Bus (one of two primary components in the DC Bus)
Link Reactors	Inductors used with the Power Capacitors (one of two primary components in the DC Bus)
PWR LED	Power Supply Light Emitting Diode- A Green Indicator on the ISB that indicates the ISB is energized.
SIG LED	Signal Light Emitting Diode – a Green Indicator on the ISB that shows the ISB is sending signals to the IGBT. At frequencies lower than 15 hz it is easy to see that the light is blinking on and off, but if the frequency is greater than 30 hz the light looks like it is on all the time.
FLT LED	Fault Light Emitting Diode – A red indicator light on the ISB that when illuminated indicates that an IOT condition has occurred. Note: The IOT LED will not stay on continuously but will illuminate for a time after the IOT occurs.
Consistent Pattern	The IOT Alarm is associated with the same phase or the same group of phases each time it occurs. Polarity (+ or -) does not matter when evaluating the pattern.
Random Pattern	The IOT Alarm does not manifest in a predictable phase or the same group of phases each time it occurs.

5 General Troubleshooting Flow Charts

The following section provides several troubleshooting flow charts that will assist the user in diagnosing problems with an Electrospeed Advantage drive. The illustration below depicts the symbols used in the charts and lists their associated functions.

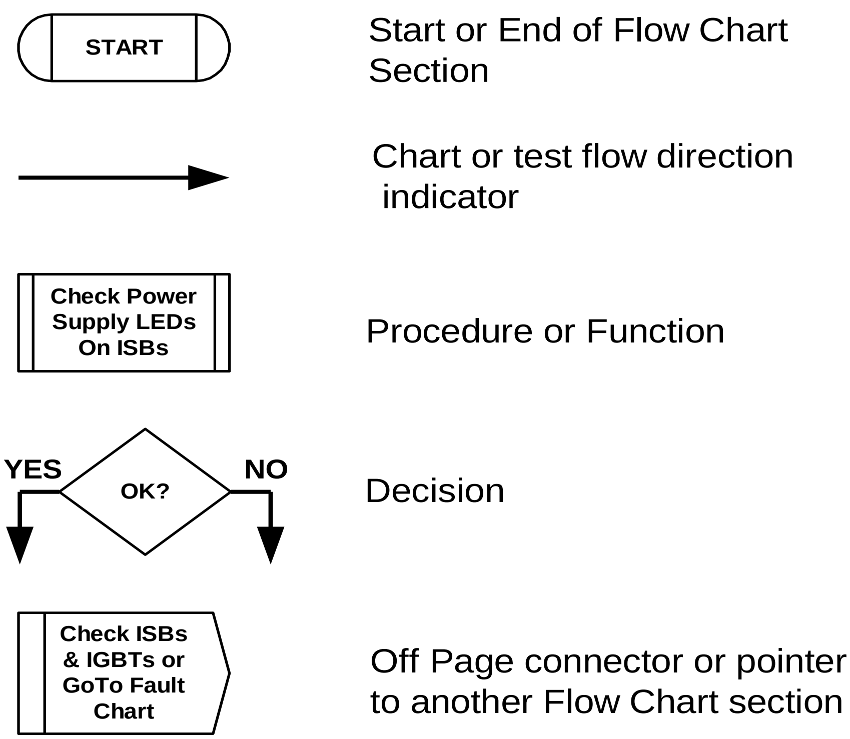


Figure 22: Flow chart symbol definitions

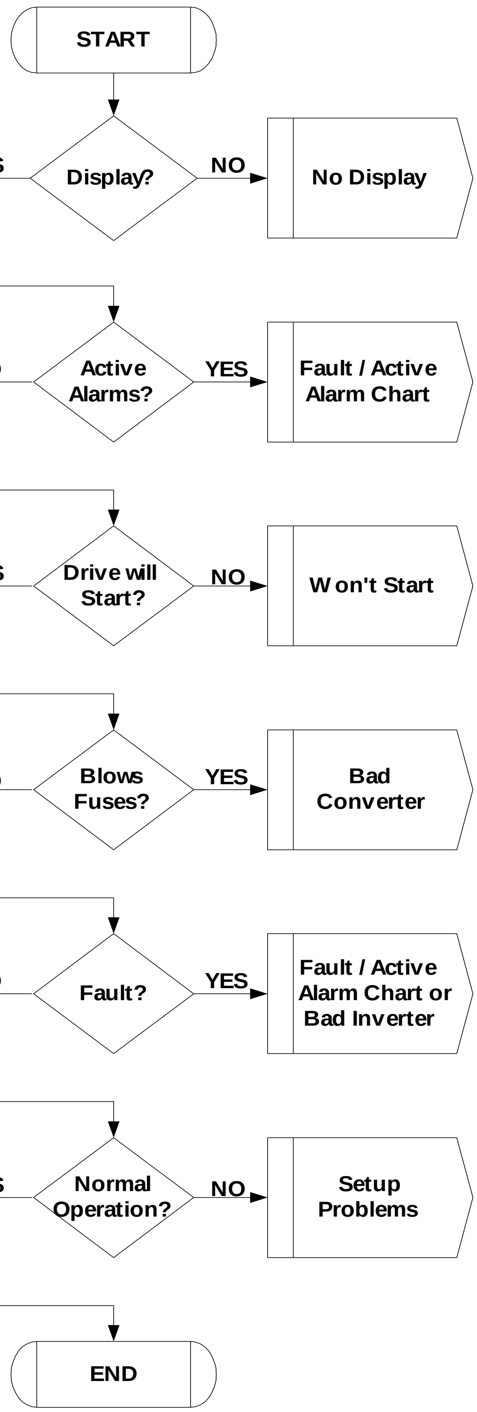


Figure 23: Diagnostic overview flow chart

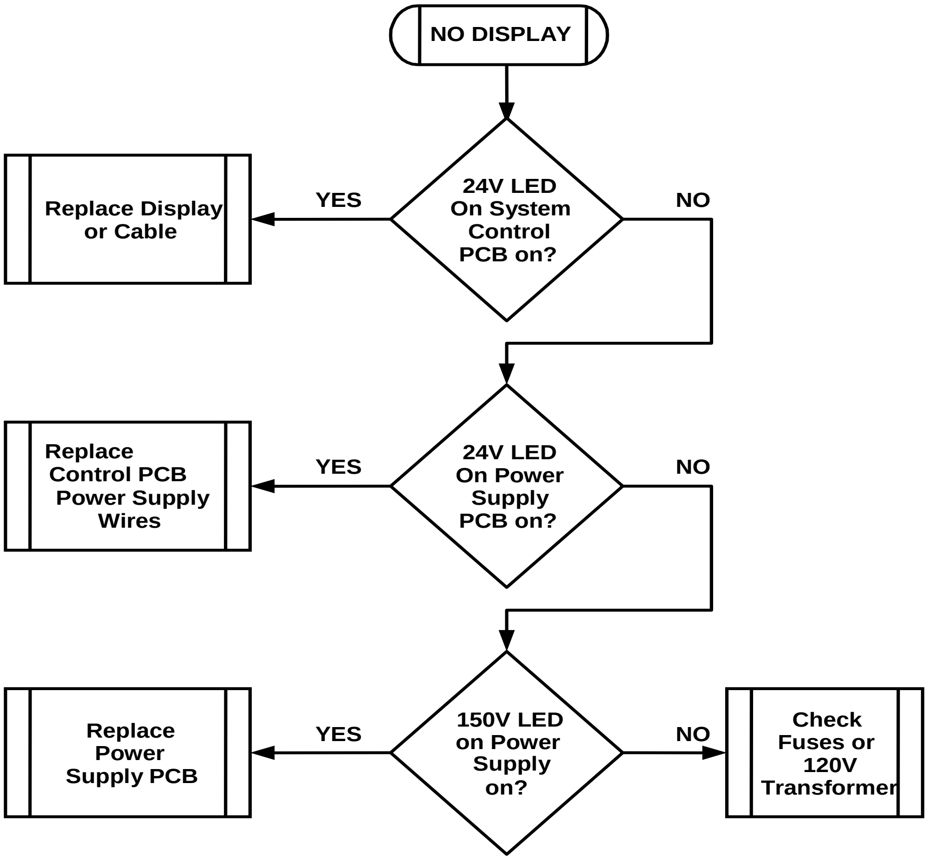


Figure 24: Display problem flow chart

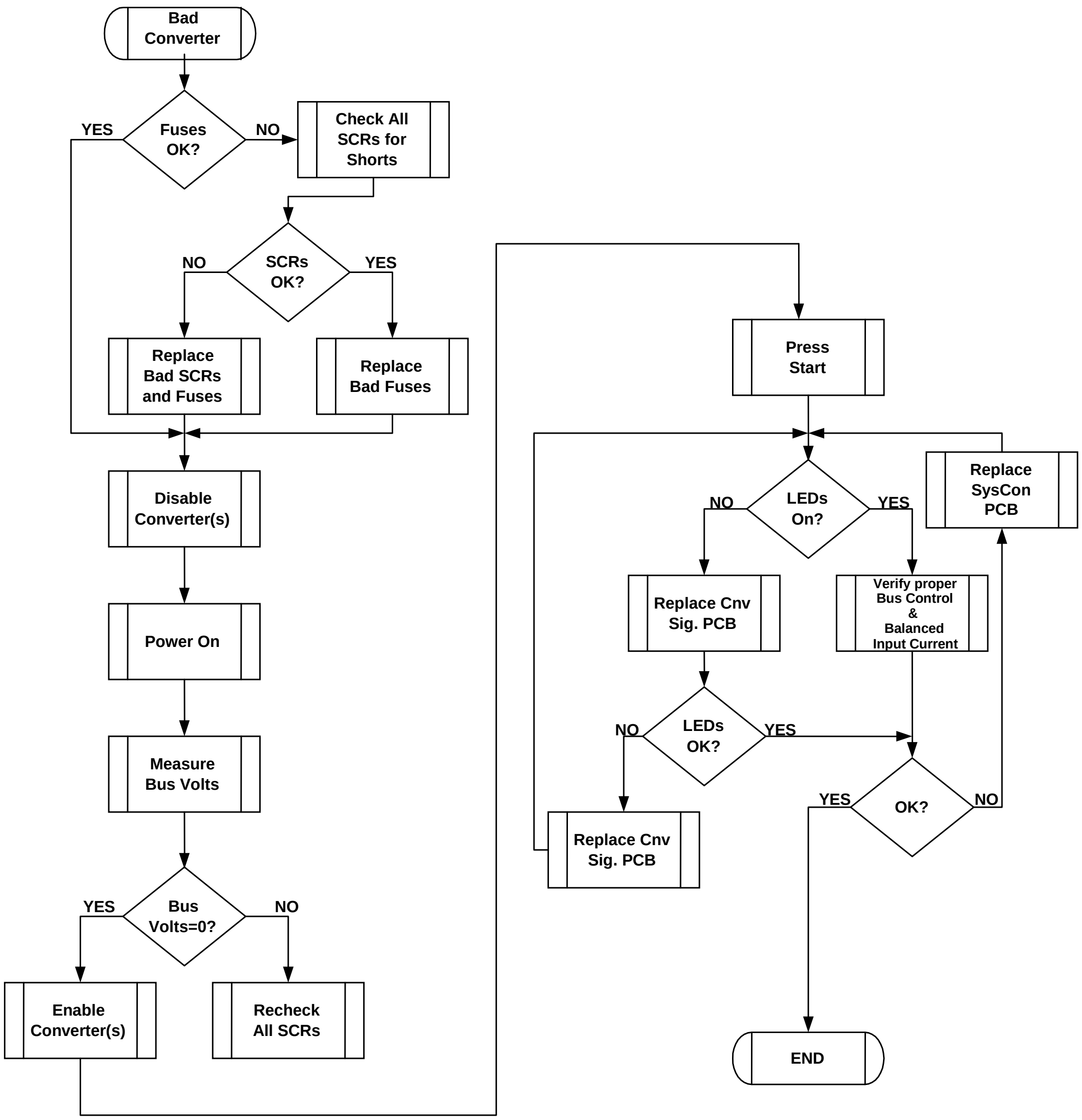


Figure 25: Converter problem flow chart

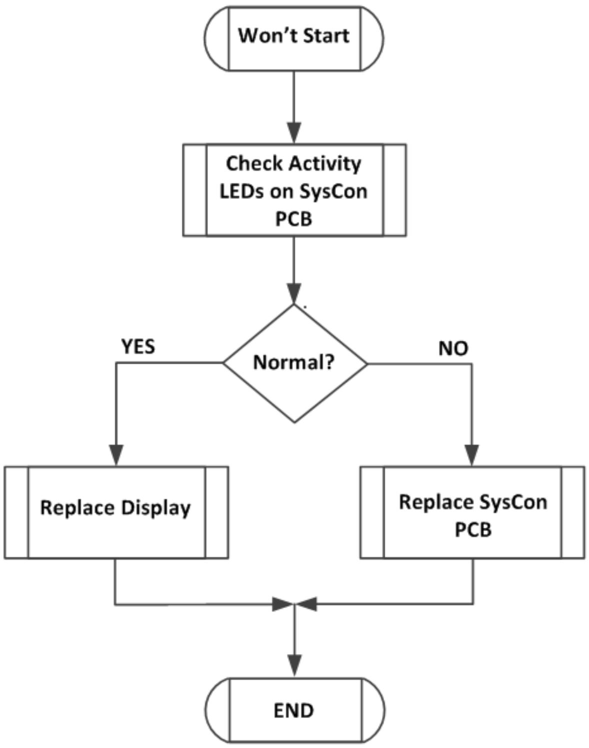


Figure 26: Starting problems flow chart

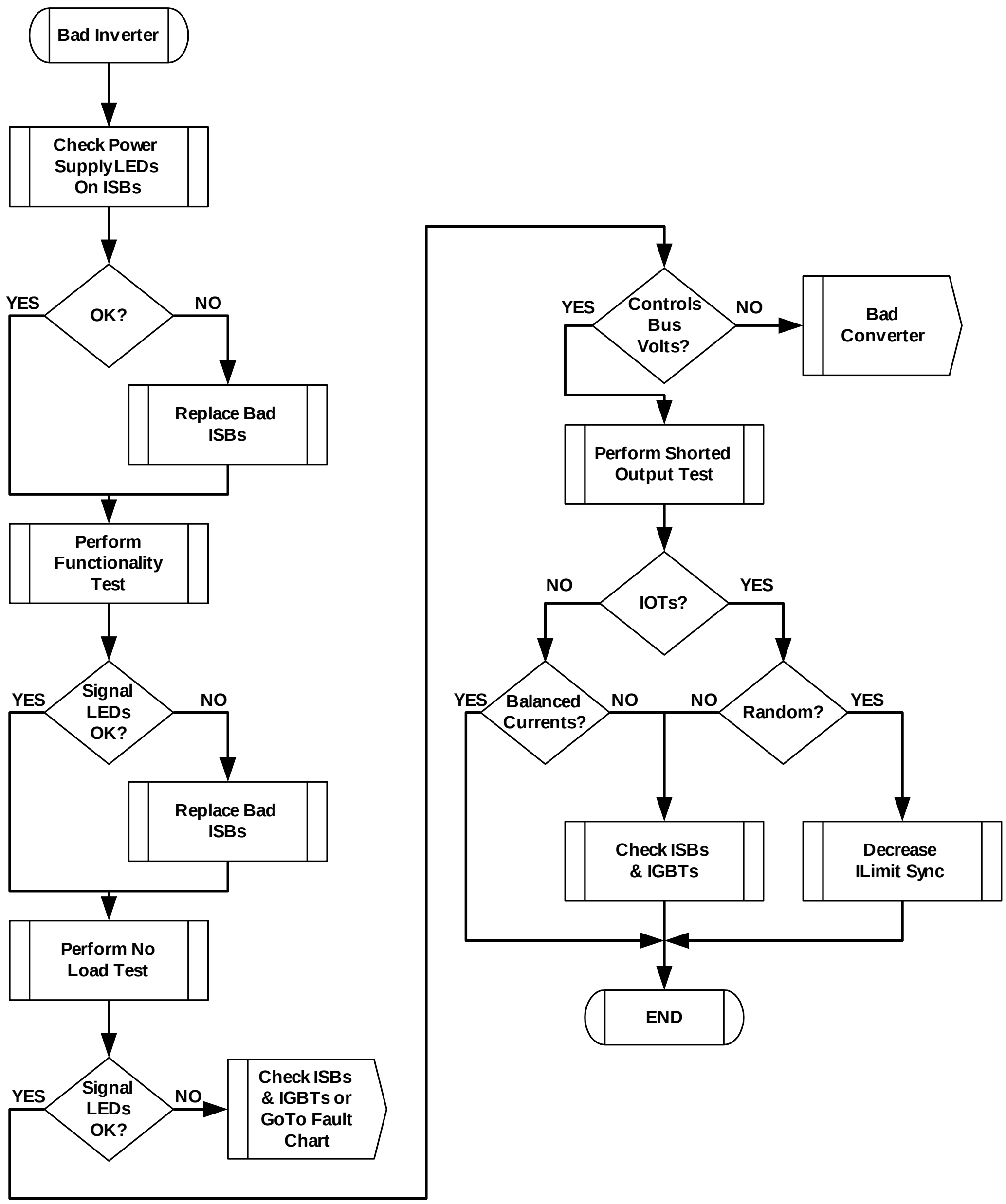


Figure 27: Inverter problems flow chart

6 Control Supply Troubleshooting

In Advantage, the 480V (connected to the BPSB through J1) comes from/before the main line fuses FU1 and FU2 (schematic 907195). If the drive's main disconnect switch is switched ON but the display is not coming up, use the following troubleshooting steps:

On the BPSB, if D9 (150VDC) is ON and D8 (24VDC) is ON, the problem is between J5 connector and the ASCB/BSCB.

If D9 is ON but D8 is OFF, this means that F1 and F2 (480V fuse protecting CPT1) are ok, F5 (overload protection of the input of the BPSB) is ok, and the AC to DC converter section of the BPSB is also ok. Therefore, F7 needs to be checked. If F7 is ok, or it is replaced but D8 is still not coming ON, the DC-DC1 is malfunctioning and the BPSB has to be replaced.

If neither the D9 nor D8 is ON, check F5, F1, and F2. If F5 was the problem and after replacing it burned again, the Q2 or another component of the BPSB is malfunctioning and the BPSB has to be replaced.

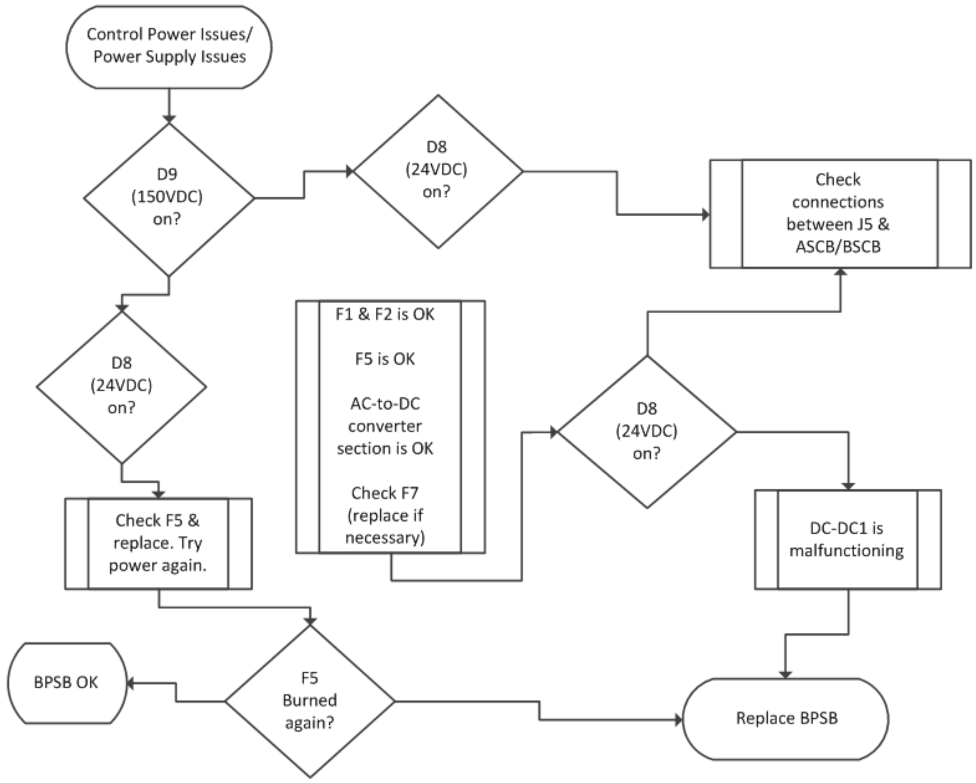


Figure 28: Control supply troubleshooting

Fault/Active Alarm Chart

An active alarm is any condition, other than a manual stop (pressing the STOP button) which can cause the drive to stop. Most alarm conditions have an associated timer that can be used to delay shutdown for some period of time. When the unit stops, the active alarm is considered a shutdown, and is stored as such in the shutdown history. Although the names fault and alarm imply problems, an active alarm may not necessarily mean that something is wrong. Some can be caused by a normal external process condition which causes the drive to stop for some period of time. Others are actual problems detected by the drive itself. While the conditions that cause any active alarm are present, the alarm will be annunciated on the status screen in the area labeled active alarms. After a shutdown, the area of the status screen marked LST Shtdn will indicate which active alarm caused the last shutdown of the drive.

Most active alarms have an associated bypass delay timer which determines how long an active alarm will be ignored after a start is initiated, and a shutdown delay timer which determines how long the active alarm must be valid before a shutdown occurs. In addition, most can be disarmed or set to cause the drive to lockout or stop permanently as a result of the alarm. A few of the alarms, such as heat sink temperatures, can only be monitored but not edited as they affect the operation of the drive.

The faults/active alarms can be loosely grouped into six categories. These are:

- Operational thresholds
- Onboard inputs/outputs
- External inputs/outputs
- Software faults
- Hardware faults
- Other

Each group will be discussed in detail in the following sections.

Operational Thresholds

Operational thresholds refer to any number of measured or calculated real-time parameters. Many of these can be set up to cause a shutdown of the drive if the value of the parameter crosses a user-defined threshold. Some, such as the input voltage, are monitored because they can affect the operation of the drive if outside of nominal values. Others, such as output current, are used to monitor and protect the load.

Onboard I/O

The system base board has built-in digital and analog I/O that can be used to start, stop and control the drive frequency. Each digital input can be programmed to trigger a stop in either state (active high or active low). Each analog input has an associated upper and lower threshold that can be armed to trigger a stop.

External I/O

Each external I/O module has digital and analog inputs that are used in a similar manner to the onboard I/O. The primary difference is in the way that the active alarms are displayed.

Software Faults

The Advantage drive uses several microprocessors which are in constant communication and continuously monitoring and verifying normal operation. Certain internal errors such as timing errors or serial communications errors will cause a shutdown and an annunciated fault/alarm. Most of these faults will cause an instantaneous shutdown and have no associated setup parameters.

Hardware Faults

These classes of faults/alarms generally refer to some dedicated internal piece of hardware that has detected improper operation, or some measured value that is out of limits. In addition, these faults are focused on the proper operation and protection of the actual drive hardware rather than the load or motor that is connected to the drive. With the exception of the auxiliary temperature alarm, these alarms do not have customer settable parameters.

Other Faults/Alarms

There are a number of other messages that can appear on the status screen which are not faults or alarms. Although they do appear in the active alarm area of the status screen, they are indications of a specific status or condition that affects the operation of the drive.

Table 6: Advantage Alarm Codes With Descriptions

Alarm Code (Point ID Numbers)	Alarm Code as Displayed	Alarm can be Enabled or Disabled in Drive Setup	(Manual Reference) Engineering Description	Description	Recommended Corrective Action
50	AI1 Hi Shtdn	Yes	(Onboard I/O) Analog Input 1 High Threshold Shutdown	Analog Input 1 has exceeded the value of the High Threshold setpoint	This is an alarm from an external source. Determine the cause of the excessive Analog Signal 1 and adjust High Threshold parameters if needed. If the alarm is in error, then check the signal sources to confirm if the signal is correct. If the signal is correct and drive is not displaying correct value, then check the setup for proper scaling and signal configuration. For the Advantage drive, ensure the S1-2 switch on the system board is in correct position for 0–10 VDC or 4-20 mA input. For the GCS, a 500-ohm resistor must be connected in parallel with the analog input for a 4-20 mA signal.
61	AI1 Lo Shtdn	Yes	(Onboard I/O) Analog Input 1 Low Threshold Shutdown	Analog Input 1 has fallen below the value of the Low Threshold setpoint	This is an alarm from an external source. Determine the cause of the excessive Analog Signal 1 and adjust Low Threshold parameters if needed. If the alarm is in error, then check the signal sources to confirm if the signal is correct. If the signal is correct and drive is not displaying the correct value, then check the setup for proper scaling and signal configuration. For the Advantage drive, ensure S1-2 switch on the system board is in correct position for 0-10 VDC or 4-20 mA input. For the GCS, a 500-ohm resistor must be connected in parallel with the analog input for a 4-20 mA signal.
74	AI2 Hi Shtdn	Yes	(Onboard I/O) Analog Input 2 High Threshold Shutdown	Analog Input 2 has exceeded the value of the High Threshold setpoint	This is an alarm from an external source. Determine the cause of the excessive Analog Signal 2 and adjust High Threshold parameters if needed. If the alarm is in error, then check the signal sources to confirm if the signal is correct. If signal is correct and drive is not displaying correct value, then check the setup for proper scaling and signal configuration. For the Advantage drive ensure the S1-2 switch on the system board is in correct position for 0-10 VDC or 4-20 mA input. For the GCS, a 500-ohm resistor must be connected in parallel with the analog input for a 4-20 mA signal.
84	AI2 Lo Shtdn	Yes	(Onboard I/O) Analog Input 2 Low Threshold Shutdown	Analog Input 2 has fallen below the value of the Low Threshold setpoint	This is an alarm from an external source. Determine the cause of the excessive Analog Signal 2 and adjust Low Threshold parameters if needed. If the alarm is in error, then check the signal sources to confirm if the signal is correct. If signal is correct and drive is not displaying correct value, then check setup for proper scaling and signal configuration. For the Advantage drive, ensure the S1-2 switch on the system board is in correct position for 0-10 VDC or 4-20 mA input. For GCS, a 500-ohm resistor must be connected in parallel with the analog input for a 4-20 mA signal.
92	Centl Shutdown	Yes	(Other Faults/Alarms) Central Shutdown	A remote host has requested a lockout of this drive SCADA or User PLC. The drive cannot be restarted until the host has released this condition.	No corrective action required in the VSD. Check SCADA transmitted control system; adjust or clear the variable. Another control person or process may be required depending on the system.
104	DI1 Shtdn	Yes	(Onboard I/O) Digital Input 1 Shutdown	Digital Input 1 state has changed to the value of the	Check the Digital Input 1, or change the associated setup parameters to correct the alarm. All hardware associated with this input is on the System Control PCB, so

Alarm Code (Point ID Numbers)	Alarm Code as Displayed	Alarm can be Enabled or Disabled in Drive Setup	(Manual Reference) Engineering Description	Description	Recommended Corrective Action
				Active Alarm State setpoint	failures of this board can cause erroneous readings.
116	DI2 Shtdn	Yes	(Onboard I/O) Digital Input 2 Shutdown	Digital Input 2 state has changed to the value of the Active Alarm State setpoint	Check the Digital Input 2, or change the associated setup parameters to correct the alarm. All hardware associated with this input is on the System Control PCB, so failures of this board can cause erroneous readings.
127	HOA Stop	Yes	(Onboard I/O) Hand-Off-Auto Stop	This indicates that the drive has been told (on the SCADA & Security & Systems menu) that there is an external HOA switch connected, and the drive has detected the switch in the *Off* or *Stop* position	No corrective action required in VSD. Check external switch (i.e., SCADA & Security & Systems menu).
155	Man Kpad Lk	Yes	(Other Faults/Alarms) Manual Stop/Manual Keypad Lockout	The drive has been stopped by pressing the stop key. This inhibits all automatic restarts. The drive remains stopped until it receives a start command from the keypad or a local HOA-START switch.	No Corrective action required.
159	Lockout	No	(Other Faults/Alarms) Lockout	This is an indication that some alarm has been programmed to cause a permanent stop if the alarm condition occurs. The drive will not automatically restart.	To restart the drive, it will be necessary to clear whatever condition caused the alarm, and then press the STOP button. This will clear the lockout and allow a restart. Because this will cause a manual keypad lockout, the drive will not automatically restart even if restarts are enabled. The lockout condition must be cleared before restarts are allowed. Clear the lockout by pressing the STOP keypad switch, or changing the HOA switch to OFF, then back to H or A, clear the lockout via SCADA.
175	Ovld Shtdn	No	(Operational Thresholds) Overload Shutdown	The output current of the drive has exceeded the overload setpoint for longer than the shutdown delay time.	Either decrease the output current by changing the operating frequency, or increase the overload setpoint. If the problem is a transient condition, lengthening the shutdown delay can help.
178	Input V Sag	No	(Other Faults/Alarms) Input Voltage Sag	The Advantage drive has detected a sag in the magnitude of the input voltage. It will attempt to continue operating during the power sag as long as it has stored energy to use. In the average installation, the drive can maintain its output for up to 25mSec. If	The drive cannot compensate for intermittent power failures, only attempt to ride through the event. If desired, the Advantage can be fitted with an external capacitive energy store unit that will allow the drive to ride through faults lasting up to 500mSec.

Alarm Code (Point ID Numbers)	Alarm Code as Displayed	Alarm can be Enabled or Disabled in Drive Setup	(Manual Reference) Engineering Description	Description	Recommended Corrective Action
				the input voltage sag persists longer than it can maintain operation, the drive will shut down and annunciate the fault as a *Power Fail Shutdown*. If it does keep the motor running through the power disturbance, it will annunciate an *Input Voltage Sag* event.	
187	OvrVlt Shtdn	Yes	(Operational Thresholds) Overvoltage Shutdown	The input voltage to the drive is higher than the overvoltage setpoint	
207	PCM Sys Err	No	(Software Faults) PCM System Error	This is a catchall fault related to internal errors in the 68332. Included are items such as: divide by zero and data bus failures. This fault implies a type of improper processor operation.	This fault should only be seen rarely. If it occurs repeatedly, the only action to take is to replace the system base board.
193	PCM Flt	No	(Software Faults) PCM Fault	The Power Conversion Module (PCM) has determined that the Converter/ Inverter Software module has quit operating	Although the shutdown routine will attempt a restart of the software module, a sure way to recover from this fault is to cycle power to the unit. This reinitializes all software and restores normal operation. This is normally associated with input power issues.
200	Ø A Neg IOT	No	(Hardware Faults) Phase A Negative Instant Overcurrent Trip	An IOT condition has been detected in the Phase A Negative. The device connected to the negative bus bar.	Consult the section of this manual titled: Instantaneous Overcurrent Trip (IOT) Condition- Define and Measure Overview
201	Ø A Pos IOT	No	(Hardware Faults) Phase A Positive Instant Overcurrent Trip	An IOT condition has been detected in the Phase A Positive. The device connected to the negative bus bar.	Similar to Phase A Negative Instant Overcurrent Trip.
202	Ø B Neg IOT	No	(Hardware Faults) Phase B Negative Instant Overcurrent	An IOT condition has been detected in the Phase B Negative. The device connected to the negative	Similar to Phase A Negative Instant Overcurrent Trip.

Alarm Code (Point ID Numbers)	Alarm Code as Displayed	Alarm can be Enabled or Disabled in Drive Setup	(Manual Reference) Engineering Description	Description	Recommended Corrective Action
			Trip	bus bar.	
203	Ø B Pos IOT	No	(Hardware Faults) Phase B Positive Instant Overcurrent Trip	An IOT condition has been detected in the Phase B Positive. The device connected to the negative bus bar.	Similar to Phase A Negative Instant Overcurrent Trip.
204	Ø C Neg IOT	No	(Hardware Faults) Phase C Negative Instant Overcurrent Trip	An IOT condition has been detected in the Phase C Negative. The device connected to the negative bus bar.	Similar to Phase A Negative Instant Overcurrent Trip.
205	Ø C Pos IOT	No	(Hardware Faults) Phase C Positive Instant Overcurrent Trip	An IOT condition has been detected in the Phase C Positive. The device connected to the negative bus bar.	Similar to Phase A Negative Instant Overcurrent Trip.
268	Undrld Shtdn	Yes	(Operational Thresholds) Underload Shutdown	The output current of the drive has fallen below the Underload setpoint for longer than the shutdown delay time.	Either increase the output current by changing the operating frequency, or decrease the Underload setpoint. If the problem is a transient condition, lengthening the shutdown delay can help.
280	UndrVlt Shtdn	Yes	(Operational Thresholds) Under Voltage Shutdown	The input voltage to the drive is lower than the Undervoltage setpoint.	Check the input power or adjust the undervoltage setpoint. Also, since the input voltage is monitored through the SCR gate leads, loose gate leads or a damaged CSB could cause this symptom.
306	Vunbal Shtdn	Yes	(Operational Thresholds) Voltage Unbalance Shutdown	The magnitudes or percent of three input voltages which have exceeded the value of the Voltage Unbalance setpoint.	Check the input power or adjust the voltage unbalance setpoint. If the setpoint correct check the converter hardware can affect these values.
314	Inv Freq Alm	No	(Other Faults/Alarms) Inverter Frequency Alarm	Inverter Frequency Alarm	
325	PCM Ø Lock	No	(Software Faults) PCM Phase Lock	The PCM is unable to determine the input power phasing.	
342	PCM Com Err	No	(Software Faults) PCM Communications Error	The PCM has ceased communicating on the	PCM processor has ceased communicating. Since there are no setup parameters that can affect this, the only action to take is to identify the errant hardware and

Alarm Code (Point ID Numbers)	Alarm Code as Displayed	Alarm can be Enabled or Disabled in Drive Setup	(Manual Reference) Engineering Description	Description	Recommended Corrective Action
				internal serial bus.	replace it with a new component.
344	Cnvtr Flt	No	(Software Faults) Converter Fault	The internal watchdog timer for the PCM has determined that the Converter Software module has quit operating.	This fatal fault will always cause a shutdown as it implies that the converter has quit functioning. Although the shutdown routine will attempt a restart of the software module, a sure way to recover from this fault is to cycle power to the unit. This reinitializes all software and restores normal operation.
345	Invtr Flt	No	(Software Faults) Inverter Fault	The internal watchdog timer for the PCM has determined that the Inverter Software module has quit operating.	Similar to the converter fault—If the drive does not recover automatically, cycle the power.
394	HS1 Shtdn	No	(Hardware Faults) Heat Sink 1 Shutdown	The temperature of Heat Sink 1 has exceeded the preset value.	Depending on the drive size, there will be from 1–4 heat sink temperature sensors. Each sensor approximately monitors the operation of one external cooling fan due to the physical location of the sensors. If only one sensor indicates an over-temperature, first check the cooling fan associated with that sensor. Also, as with other cooling related problems, ensure the air path is not obstructed. If the cooling fans appear to be operating correctly, check the temperature sensor and wiring by temporarily connecting them to a different input. If necessary, replace the System Control PCB.
406	HS2 Shtdn	No	(Hardware Faults) Heat Sink 2 Shutdown	The temperature of Heat Sink 2 has exceeded the preset value.	Depending on the drive size, there will be from 1–4 heat sink temperature sensors. Each sensor approximately monitors the operation of one external cooling fan due to the physical location of the sensors. If only one sensor indicates an over-temperature, first check the cooling fan associated with that sensor. Also, as with other cooling related problems, ensure that the air path is not obstructed. If the cooling fans appear to be operating correctly, check the temperature sensor and wiring by temporarily connecting it to a different input. If necessary, replace the System Control PCB.
418	HS3 Shtdn	No	(Hardware Faults) Heat Sink 3 Shutdown	The temperature of Heat Sink 3 has exceeded the preset value.	Depending on the drive size, there will be from 1–4 heat sink temperature sensors. Each sensor approximately monitors the operation of one external cooling fan due to the physical location of the sensors. If only one sensor indicates an over-temperature, first check the cooling fan associated with that sensor. Also, as with other cooling related problems, ensure that the air path is not obstructed. If the cooling fans appear to be operating correctly, check the temperature sensor and wiring by temporarily connecting it to a different input. If necessary, replace the System Control PCB.
430	Heatsink 4	No	(Hardware Faults) Heat Sink 4 Shutdown	The temperature of Heat sink 4 has exceeded the preset value.	Depending on the drive size, there will be from 1–4 heat sink temperature sensors. Each sensor approximately monitors the operation of one external cooling fan due to the physical location of the sensors. If only one sensor indicates an over-temperature, first check the cooling fan associated with that sensor. Also, as with other cooling related problems, ensure that the air path is not obstructed. If the cooling fans appear to be operating correctly, check the temperature sensor and wiring by temporarily connecting it to a different input. If necessary, replace the

Alarm Code (Point ID Numbers)	Alarm Code as Displayed	Alarm can be Enabled or Disabled in Drive Setup	(Manual Reference) Engineering Description	Description	Recommended Corrective Action
					System Control PCB.
442	Ind Tmp Shtd	No	(Hardware Faults) Inductor Temp Shutdown	The temperature of the link reactor(s) (inductor) has exceeded the allowable threshold.	High inductor temperature can be caused by either improper cooling, or improper drive operation. First, verify that the cooling fans are operational and that the base of the drive is not blocked by foreign material. Also, ensure that the ambient temperature is not above that rated for the drive under the present operating conditions. If these conditions are all ok, then check for possible improper operation. The temperature of the link reactors is (in some operating modes) directly proportional to difference between input and output voltage of the drive. Therefore, it is desirable to operate the drive at the highest possible output voltage. This is especially true if the drive is heavily loaded. If necessary, readjust the operating frequency setpoint.
454	Amb Tmp Shtdn	No	(Hardware Faults) Ambient Temperature Shutdown	The internal ambient temperature has exceeded 85°C.	This temperature sensor is located on the system base board. Therefore, it measures the internal drive temperature. First, check the small fan(s) blowing air through the air-to-air heat exchanger. If they are inoperative, check the power supply board fuses first, then check the fans themselves. These fans are switched on and off with a relay on the power supply board, so a failure of that board could also cause this symptom. Finally, the system base board itself could give a false reading if the board is damaged.
468	Aux Tmp Shtdn	Yes	(Operational Thresholds) Auxiliary Temperature Shutdown	The Auxiliary Temperature input has exceeded its set threshold.	This input is for customer use. Its operating parameters are completely adjustable by the customer. As a result, this is not a fault as much as it is an annunciation. An occurrence of this alarm can be corrected by either changing the condition of the monitored equipment, or changing the setup parameters for this input.
478	Lo Speed Shtdn	Yes	(Operational Thresholds) Low Speed Shutdown	The Drive Output frequency has fallen below the Low Speed Clamp setpoint for longer than the shutdown delay time.	The frequency setpoint cannot be set below the low speed clamp and the only thing that can override this is ILimit, this fault will normally indicate that the load on the drive has increased dramatically. As the load increases, the ILimit function will cause the drive to slow down in an attempt to control output current. If this effect is severe enough, the output frequency will fall below the set point, generating a low speed trip. Check the motor and load for problems.
482	AGD Comm Fail	No	(Software Faults) Advantage Graphic Display	Advantage Graphic Display communication failure	
572	DI3 Shtdn	Yes	(Onboard I/O) Digital Input 3 Shutdown	Digital Input 3 state has changed to the value of the Active Alarm State setpoint.	Check the Digital Input 3 or change the associated setup parameters to correct the alarm. All hardware associated with this input is on the System Control PCB; therefore failures of this board can cause erroneous readings.
608	Man Kpad Lk	No	(Other Faults/Alarms) Drive stopped manually	The drive has been stopped by pressing the STOP key. This inhibits all automatic restarts. The drive remains stopped until it receives a start command from the	None required.

Alarm Code (Point ID Numbers)	Alarm Code as Displayed	Alarm can be Enabled or Disabled in Drive Setup	(Manual Reference) Engineering Description	Description	Recommended Corrective Action
				keypad or a local HOA-START switch.	
610	SCADA Stop	Yes	(Other Faults/Alarms) SCADA Stop	SCADA stop	
626	PCM Bus Vlts	No	(Other Faults/Alarms) PCM Bus Vlts	This is an indication there is voltage present on the DC bus. During a normal stop, the bus voltage goes to zero. Certain faults and the E-stop mode can temporarily leave voltage on the bus. In the 6-step and Hybrid Inverter modes, voltage on the bus will inhibit starting. Therefore, this status indication informs the operator when a start is not possible.	This is an indication there is voltage present on the DC bus. During a normal stop, the bus voltage goes to zero. Certain faults and the E-stop mode can temporarily leave voltage on the bus. In the 6-step and Hybrid Inverter modes, voltage on the bus will inhibit starting. Therefore, this status indication informs the operator when a start is not possible.
640	Serial Com	No	(Software Faults) Serial communications error	There has been an unrecoverable error in the RS-232 communications.	This problem can be caused by either improper setup or actual hardware problems. First check the SCADA settings on the SCADA & Security & Systems menu. Ensure they are the same as those on the host computer trying to communicate. If that does not correct the problem, try a slower baud rate to see if throughput is the problem. The TX and RX LEDs mounted on the circuit board near the port connector provide an indication of whether the system is receiving or transmitting data. If all tests appear normal, replace the system control circuit board.
642	Tel Fail Sd Dly	Yes	(Other Faults/Alarms) Telemetry Fail Shutdown Delay	Telemetry Fail Shutdown delay	
647	Invld Alm	Yes	(Other Faults/Alarms) Invalid Clock Alarm	The real-time clock has an invalid time.	Usually this status is seen after a software reload—all of the internal data are written over to defaults. All that is necessary is to go the SCADA & Security & System menu and reset the clock to the current time/date. This can also occur if the battery has discharged.
814	RD1 Com Fail Alm Shtdn	No	(Software Faults) Remote Device One Communications Failure Alarm Shutdown	Remote Device One Communications Failure Alarm shutdown	
827	RDCM Com Fail	No	(Software Faults) Remote Data Communication	Remote Data Communication Module Communication failure	

Alarm Code (Point ID Numbers)	Alarm Code as Displayed	Alarm can be Enabled or Disabled in Drive Setup	(Manual Reference) Engineering Description	Description	Recommended Corrective Action
			Module Communication Failure		
859	Mtr State Sync Err	No	(Software Faults) Motor State Sync Error	The Advantage System Controller (ASC) has determined that the state of the Advantage Power Conversion (APC) module is different from what has been commanded (e.g., running after a stop command).	Typically, none is required. This should only be a transient condition as the system controller and the PCM communicate with each other. If this condition persists, cycle the power to the drive to reset the software.
870	Max Starts	No	(Operational Thresholds) Maximum Starts	When auto restarts are enabled, the Maximum Allowed Starts parameter determines how many times the drive will be allowed to restart after a fault. When this number of starts has been reached, the drive will stop with a Max Starts lockout.	To reset the starts counter and begin the process again, it is only necessary to press the STOP button. As with any lockout, it will be necessary to make the first start manually with the START button, a digital input, or a remote host.
872	1st Strt	No	(Other Faults/Alarms) First Start	This is simply an indication that the system control software has been updated since the last start.	Although no action is required, this is a reminder to check all the setup parameters to ensure they have not been changed during the reprogramming. Be aware that the Advantage Drive will not allow an automatic start as the first start. At least one manual start is required.
895	X1 AI1 Hi Shtdn	Yes	(External I/O) Exp I/O 1 AI1 High Threshold Shutdown	The Expansion I/O Module 1, Analog Input 1 has exceeded the value of the High Threshold setpoint.	Determine the cause of the excessive I/O 1, Analog Signal 1, or adjust High Threshold parameters. Check the Expansion I/O 1—all hardware associated with this input is on the Expansion I/O 1 module, so failures of this board can cause erroneous readings.
909	X1 AI2 Hi Shtdn	Yes	(External I/O) Exp I/O 1 AI2 High Threshold Shutdown	The Expansion I/O Module 1, Analog Input 2 has exceeded the value of the High Threshold setpoint.	Determine the cause of the excessive I/O 1, Analog Signal 2, or adjust High Threshold parameters. Check the Expansion I/O 1—all hardware associated with this input is on the Expansion I/O 1 module, so failures of this board can cause erroneous readings.
923	X2 AI1 Hi Shtdn	Yes	(External I/O) Exp I/O 2 AI1 High Threshold Shutdown	The Expansion I/O Module 2, Analog Input 1 has exceeded the value of the High Threshold setpoint.	Determine the cause of the excessive I/O 2, Analog Signal 1, or adjust High Threshold parameters. Check the expansion I/O 2—all hardware associated with this input is on the Expansion I/O 2 module, so failures of this board can cause erroneous readings.
937	X2 AI2 Hi Shtdn	Yes	(External I/O) Exp I/O 2 AI2 High Threshold	The Expansion I/O 2, Analog Input 2 has	Determine the cause of the excessive I/O 2, Analog Signal 2, or adjust High Threshold parameters. Check the Expansion I/O 2—all hardware associated with

Alarm Code (Point ID Numbers)	Alarm Code as Displayed	Alarm can be Enabled or Disabled in Drive Setup	(Manual Reference) Engineering Description	Description	Recommended Corrective Action
			Shutdown	exceeded the value of the High Threshold setpoint.	this input is on the Expansion I/O 2 module, so failures of this board can cause erroneous readings.
951	X3 AI1 Hi Shtdn	Yes	(External I/O) Exp I/O 3 AI1 High Threshold Shutdown	The Expansion I/O Module 3, Analog Input 1 has exceeded the value of the High Threshold setpoint.	Determine the cause of the excessive I/O 3, Analog Signal 1, or adjust High Threshold parameters. Check the Expansion I/O 3—all hardware associated with this input is on the Expansion I/O 3 module, so failures of this board can cause erroneous readings.
965	X3 AI2 Hi Shtdn	Yes	(External I/O) Exp I/O 3 AI2 High Threshold Shutdown	The Expansion I/O Module 3, Analog Input 2 has exceeded the value of the High Threshold setpoint.	Determine the cause of the excessive I/O 3, Analog Signal 2 or adjust High Threshold parameters. Check the Expansion I/O 3—all hardware associated with this input is on the Expansion I/O 3 module, so failures of this board can cause erroneous readings.
978	X1 DI1 Shtdn	Yes	(External I/O) Exp I/O 1 DI1 Shutdown	The Expansion I/O Module 1, Digital Input 1 state has changed to the value of the Active Alarm State setpoint.	Check I/O Module 1, the Digital Input 1, or change the associated setup parameters to correct the alarm. All hardware associated with this input is on the Expansion I/O 1 module, so failures of this board can cause erroneous readings.
991	X1 DI2 Shtdn	Yes	(External I/O) Exp I/O 1 DI2 Shutdown	The Expansion I/O Module 1, Digital Input 2 state has changed to the value of the Active Alarm State setpoint.	Check I/O Module1, the Digital Input 2, or change the associated setup parameters to correct the alarm. All hardware associated with this input is on the Expansion I/O 1 module, so failures of this board can cause erroneous readings.
1004	X1 DI3 Shtdn	Yes	(External I/O) Exp I/O 1 DI3 Shutdown	The Expansion I/O Module 1, Digital Input 3 state has changed to the value of the Active Alarm State setpoint.	Check I/O Module1, the Digital Input 3, or change the associated setup parameters to correct the alarm. All hardware associated with this input is on the Expansion I/O 1 module, so failures of this board can cause erroneous readings.
1017	X2 DI1 Shtdn	Yes	(External I/O) Exp I/O 2 DI1 Shutdown	The Expansion I/O Module 2, Digital Input 1 state has changed to the value of the Active Alarm State setpoint.	Check I/O Module2, the Digital Input 1, or change the associated setup parameters to correct the alarm. All hardware associated with this input is on the Expansion I/O 2 module, so failures of this board can cause erroneous readings.
1030	X2 DI2 Shtdn	Yes	(External I/O) Exp I/O 2 DI2 Shutdown	The Expansion I/O Module 2, Digital Input 2 state has changed to the value of the Active Alarm State setpoint.	Check I/O Module 2, the Digital Input 2, or change the associated setup parameters to correct the alarm. All hardware associated with this input is on the Expansion I/O 2 module, so failures of this board can cause erroneous readings.
1043	X2 DI3 Shtdn	Yes	(External I/O) Exp I/O 2 DI3 Shutdown	The Expansion I/O Module 2, Digital Input 3 state has changed to the value of the Active Alarm State setpoint.	Check I/O Module 2, the Digital Input 3, or change the associated setup parameters to correct the alarm. All hardware associated with this input is on the Expansion I/O 2 module, so failures of this board can cause erroneous readings.
1056	X3 DI1 Shtdn	Yes	(External I/O) Exp I/O 3 DI1 Shutdown	The Expansion I/O Module 3, Digital Input 1 state has changed to the value of the	Check I/O Module 3, the Digital Input 1, or change the associated setup parameters to correct the alarm. All hardware associated with this input is on the Expansion I/O 3 module, so failures of this board can cause erroneous readings.

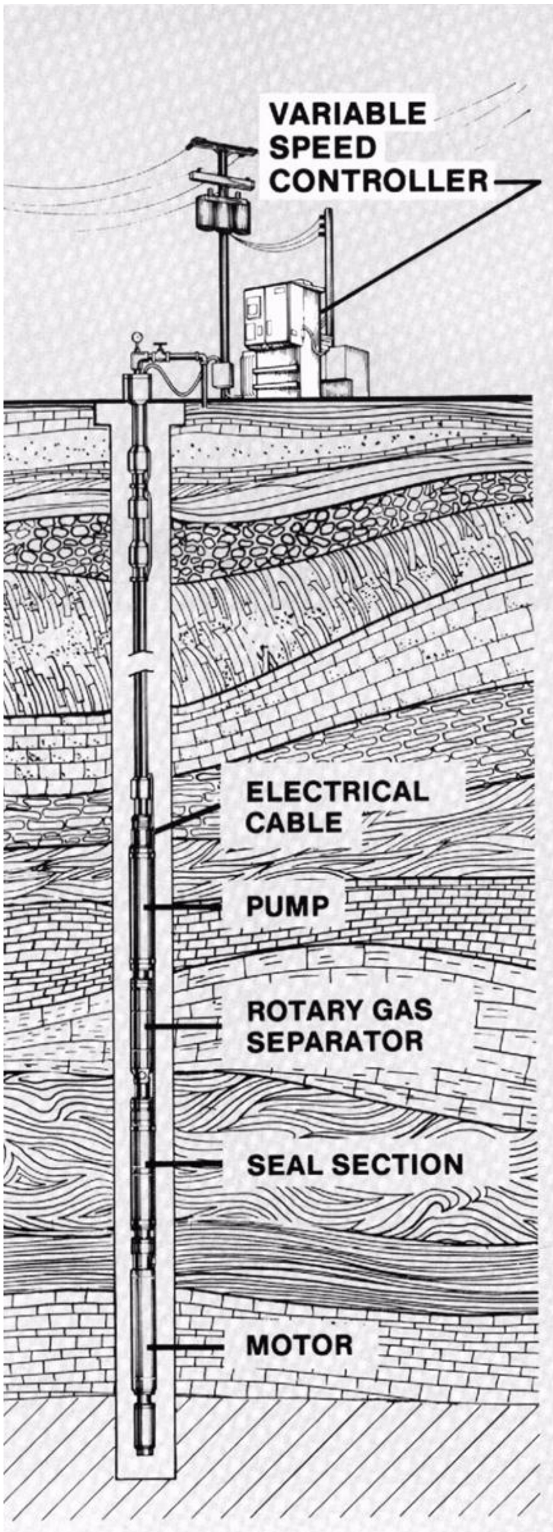
Alarm Code (Point ID Numbers)	Alarm Code as Displayed	Alarm can be Enabled or Disabled in Drive Setup	(Manual Reference) Engineering Description	Description	Recommended Corrective Action
				Active Alarm State setpoint.	
1069	X3 DI2 Shtdn	Yes	(External I/O) Exp I/O 3 DI2 Shutdown	The Expansion I/O Module 3, Digital Input 2 state has changed to the value of the Active Alarm State setpoint.	Check I/O Module 3, the Digital Input 2, or change the associated setup parameters to correct the alarm. All hardware associated with this input is on the Expansion I/O 1 module, so failures of this board can cause erroneous readings.
1082	X3 DI3 Shtdn	Yes	(External I/O) Exp I/O 3 DI3 Shutdown	The Expansion I/O Module 3, Digital Input 3 state has changed to the value of the Active Alarm State setpoint.	Check I/O Module 3, the Digital Input 3, or change the associated setup parameters to correct the alarm. All hardware associated with this input is on the Expansion I/O 3 module, so failures of this board can cause erroneous readings.
1096	X1 AI1 Lo Shtdn	Yes	(External I/O) Exp I/O 1 AI1 Low Threshold Shutdown	The Expansion I/O Module 1, Analog Input 1 has fallen below the value of the Low Threshold setpoint.	Determine the cause of the low I/O Module1, Analog Signal 1 level, or adjust the Low Threshold parameters. Check the Expansion I/O 1—all hardware associated with this input is on the Expansion I/O 1 module, so failures of this board can cause erroneous readings.
1109	X1 AI2 Lo Shtdn	Yes	(External I/O) Exp I/O 1 AI2 Low Threshold Shutdown	The Expansion I/O Module 1, Analog Input 2 has fallen below the value of the Low Threshold setpoint.	Determine the cause of the low I/O Module 1, Analog Signal 2 level, or adjust the Low Threshold parameters. Check the Expansion I/O 1—all hardware associated with this input is on the Expansion I/O 1 module, so failures of this board can cause erroneous readings.
1122	X2 AI1 Lo Shtdn	Yes	(External I/O) Exp I/O 2 AI1 Low Threshold Shutdown	The Expansion I/O Module 2, Analog Input 1 has fallen below the value of the Low Threshold setpoint.	Determine the cause of the low I/O Module 2, Analog Signal 1 level, or adjust the Low Threshold parameters. Check the Expansion I/O 2—all hardware associated with this input is on the Expansion I/O 2 module, so failures of this board can cause erroneous readings.
1135	X2 AI2 Lo Shtdn	Yes	(External I/O) Exp I/O 2 AI2 Low Threshold Shutdown	The Expansion I/O Module 2, Analog Input 2 has fallen below the value of the Low Threshold setpoint.	Determine the cause of the low I/O Module 2, Analog Signal 2 level, or adjust the Low Threshold parameters. Check the Expansion I/O 2—all hardware associated with this input is on the Expansion I/O 2 module, so failures of this board can cause erroneous readings.
1148	X3 AI1 Lo Shtdn	Yes	(External I/O) Exp I/O 3 AI1 Low Threshold Shutdown	The Expansion I/O Module 3, Analog Input 1 has fallen below the value of the Low Threshold setpoint.	Determine the cause of the low I/O Module 3, Analog Signal 1 level, or adjust the Low Threshold parameters. Check the Expansion I/O 3—all hardware associated with this input is on the Expansion I/O 3 module, so failures of this board can cause erroneous readings.
1161	X3 AI2 Lo Shtdn	Yes	(External I/O) Exp I/O 3 AI2 Low Threshold Shutdown	The Expansion I/O Module 3, Analog Input 2 has fallen below the value of the Low Threshold setpoint.	Determine the cause of the low I/O Module 3, Analog Signal 2 level, or adjust the Low Threshold parameters. Check the Expansion I/O 3—all hardware associated with this input is on the Expansion I/O 3 module, so failures of this board can cause erroneous readings.
1223	EIO1 Com	No	(External I/O) Exp I/O Module 1 Communication	The Expansion I/O Module 1 has ceased communicating on the internal serial bus.	EIO1 communication alarms indicate CITIBus communication failures and will only cause a shutdown if there is an enabled alarm on that I/O module. The alarm does not need to be *active* or in currently in alarm to cause this shutdown—it only has to be enabled. Expansion I/O Module 1 will indicate which processor has ceased communicating. Since there are no set up parameters that can affect this, the only

Alarm Code (Point ID Numbers)	Alarm Code as Displayed	Alarm can be Enabled or Disabled in Drive Setup	(Manual Reference) Engineering Description	Description	Recommended Corrective Action
					action to take is to identify the errant hardware and replace External I/O Module 1 with a new component.
1229	EIO2 Com	No	(External I/O) Exp I/O Module 2 Communication	The Expansion I/O Module 2 has ceased communicating on the internal serial bus.	EIO2 communication alarms indicate CITIBus communication failures and will only cause a shutdown if there is an enabled alarm on that I/O module. The alarm does not need to be *active* or in currently in alarm to cause this shutdown—it only has to be enabled. Expansion I/O Module 2 will indicate which processor has ceased communicating. Since there are no set up parameters that can affect this, the only action to take is to identify the errant hardware and replace External I/O Module 2 with a new component.
1235	EIO3 Com	No	(External I/O) Exp I/O Module 3 Communication	The Expansion I/O Module 3 has ceased communicating on the internal serial bus.	EIO3 communication alarms indicate CITIBus communication failures and will only cause a shutdown if there is an enabled alarm on that I/O module. The alarm does not need to be *active* or in currently in alarm to cause this shutdown—it only has to be enabled. Expansion I/O Module 3 will indicate which processor has ceased communicating. Since there are no set up parameters that can affect this, the only action to take is to identify the errant hardware and replace External I/O Module 3 with a new component.
1247	Cntl Com Fail Alm	Yes	(Software Faults) Centinel Communications Failure Alarm	The Centinel Communications has ceased communicating on the internal serial bus.	This alarm only indicates that the Centinel Module is no longer communicating via CITIBus to the drive. It does not mean that an alarm is actually active.
1300	NO PMOD	No	(Other Faults/Alarms) Personality Module Missing	The Personality module is missing	
1326	Converter 2 Off Lin	No	(Other Faults/Alarms) Converter 2 Off Line	The Converter 2 is offline.	Check that Converter 2 Enable/Disable switch is ENABLED. Inspect the hardware associated with Converter 2, such as converter control cards, SCR gate leads, SCRs, etc.
1360	Motor Stall	No	(Other Faults/Alarms) Motor Stall	The PCM could NOT turn the motor.	
1382	Run/Stop Dig In Alm	Yes	(Other Faults/Alarms) Run/Stop Digital Input Alarm	Run/Stop Digital Input alarm	
1394	UA 1 Shtdn	Yes	(Operational Thresholds) User Alarm 1 Shutdown	User Alarm 1–set by the user–has exceeded its parameter (i.e., the Centinel downhole gauge).	This is a user-adjustable alarm. Determine the cause of the alarm and adjust the User Alarm 1 parameters if needed. If the problem is a transient condition, lengthening the shutdown delay can help.
1407	UA 2 Shtdn	Yes	(Operational Thresholds) User	User Alarm 2–set by the user–has exceeded its parameter (e.g., the	This is a user-adjustable alarm. Determine the cause of the alarm and adjust the User Alarm 2 parameters if needed. If the problem is a transient condition,

Alarm Code (Point ID Numbers)	Alarm Code as Displayed	Alarm can be Enabled or Disabled in Drive Setup	(Manual Reference) Engineering Description	Description	Recommended Corrective Action
			Alarm 2 Shutdown	Centinel downhole gauge).	lengthening the shutdown delay can help.
1420	UA 3 Shtdn	Yes	(Operational Thresholds) User Alarm 3 Shutdown	User Alarm 3–set by the user–has exceeded its parameter (e.g., the Centinel downhole gauge).	This is a user-adjustable alarm. Determine the cause of the alarm and adjust the User Alarm 3 parameters if needed. If the problem is a transient condition, lengthening the shutdown delay can help.
1433	UA 4 Shtdn	Yes	(Operational Thresholds) User Alarm 4 Shutdown	User Alarm 4–set by the user–has exceeded its parameter (e.g., the Centinel downhole gauge).	This is a user-adjustable alarm. Determine the cause of the alarm and adjust the User Alarm 4 parameters if needed. If the problem is a transient condition, lengthening the shutdown delay can help.
1446	UA 5 Shtdn	Yes	(Operational Thresholds) User Alarm 5 Shutdown	User Alarm 5–set by the user–has exceeded its parameter (e.g., the Centinel downhole gauge).	This is a user-adjustable alarm. Determine the cause of the alarm and adjust the User Alarm 5 parameters if needed. If the problem is a transient condition, lengthening the shutdown delay can help.
1459	UA 6 Shtdn	Yes	(Operational Thresholds) User Alarm 6 Shutdown	User Alarm 6–set by the user–has exceeded its parameter (e.g., the Centinel downhole gauge).	This is a user-adjustable alarm. Determine the cause of the alarm and adjust the User Alarm 6 parameters if needed. If the problem is a transient condition, lengthening the shutdown delay can help.
1472	UA 7 Shtdn	Yes	(Operational Thresholds) User Alarm 7 Shutdown	User Alarm 7–set by the user–has exceeded its parameter (e.g., the Centinel downhole gauge).	This is a user-adjustable alarm. Determine the cause of the alarm and adjust the User Alarm 7 parameters if needed. If the problem is a transient condition, lengthening the shutdown delay can help.
1485	UA 8 Shtdn	Yes	(Operational Thresholds) User Alarm 8 Shutdown	User Alarm 8–set by the user–has exceeded its parameter (e.g., the Centinel downhole gauge).	This is a user-adjustable alarm. Determine the cause of the alarm and adjust the User Alarm 8 parameters if needed. If the problem is a transient condition, lengthening the shutdown delay can help.
1494	RD2 Com Fail Alm	No	(Software Faults) Remote Device Two Communication Failure Alarm	Remote Device Two has ceased communicating on the internal serial bus.	
1507	RD3 Com Fail Alm	No	(Software Faults) Remote Device Three Communication Failure Alarm	Remote Device Three has ceased communicating on the internal serial bus.	
1520	Cent Rx Com Fail	Yes	(Software Faults) Centinel Receiver Com Fail	Centinel Receiver communication failure	

Alarm Code (Point ID Numbers)	Alarm Code as Displayed	Alarm can be Enabled or Disabled in Drive Setup	(Manual Reference) Engineering Description	Description	Recommended Corrective Action
1642	NNI Com Fail Alarm	Yes	(Software Faults) Neuraflow Communications Failure Alarm	Neuraflow Communications has ceased communicating on the internal serial bus.	

7 Troubleshooting Electrical Submersible Pumping Systems



Introduction

This guide provides specific information pertaining to the troubleshooting of the Electrospeed Advantage VSD to the control of electrical submersible pumping (ESP) systems.

Unusual applications may require a more in-depth understanding of the Electrospeed Advantage drive than can be provided within this guide. In such cases, Baker Hughes offers classroom training courses that thoroughly cover the troubleshooting of the Electrospeed Advantage VSD.

Motor Start Troubleshooting

For troubleshooting it is recommended, where practical, the load be disconnected and the VSD operated at No-Load to verify correct operation.

After all necessary parameters have been set, press the START button. The controller will ramp quickly to the start frequency. The controller will remain at the start frequency through the sync delay period. After sync delay, the controller will accelerate the motor at the rate established by the accel time if the controller can provide sufficient current. If the controller cannot provide sufficient current, the motor will accelerate at a lower rate determined by the load inertia and the current availability.

Note: The Electrospeed Advantage controller will not restart if voltage is present on the DC bus. There will be a delay of 30 to 60 seconds between starts to allow the bus to discharge.

If the controller is unable to start the motor, check the load current during an attempted start. If it is equal to ILimit sync, increase ILimit sync and try again. Continue the process of increasing ILimit sync and start attempts until the motor starts or the load current is not limited by ILimit sync. If the motor still does not start, increase VBoost sync in 5 volt increments up to 33% of starting voltage. If the output current becomes equal to ILimit or ILimit sync, further increases of VBoost will be ineffective. If the motor still does not start, set VBoost sync to 0 and increase start frequency. Be careful in increasing VBoost sync. If the start voltage is too high for the start frequency, the motor or output transformer, if used, may saturate. This causes the excitation current to dramatically increase. In this situation, ILimit sync current may be reached, but a large portion of the current may be excitation current for the transformer or motor. For this reason it is generally best to initially attempt starting with no VBoost sync, and then increase only as necessary.

The problem of transformer saturation is particularly evident in submersible pump applications where output step-up transformers are used. Submersible applications typically include long lengths of cable between the step-up transformer and motor. Cable voltage drop is typically high, and may require some VBoost sync for motor starting. Output transformers for submersibles are typically designed to allow for intermittent overvoltages of about 33% without significant increases in excitation currents. Even with the capability of boosting output voltage by 33%, problems can still be encountered with transformer saturation. In some cases, though rare, it may be necessary to increase start frequency to obtain maximum available current without saturating the transformer. Since the voltage/frequency ratio will remain constant, neglecting VBoost sync, the output voltage will be higher at the increased start frequency. The load reactance will also increase, but the load resistance will remain constant making the increase in overall load impedance less than the increase in voltage. This will allow for more starting current without saturating the transformer. In some situations, well conditions deposit foreign material in the pump that can cause it to jam. If this is suspected, try starting the motor in the backward rotation first to free it up. Then, try a forward start again.

Optimization

After the ESP has been successfully started, several operating parameters should be checked and, if necessary, adjusted to ensure optimal operation of the system.

Input Power Factor

To ensure the best possible input power factor, adjust the output transformer tap setting to allow the converter section’s SCRs to operate at full voltage, fully phased on. The output transformer taps are selected to produce the required voltage at the motor terminals at the desired operating frequency.

Reducing Harmonic Distortion: 12-pulse Input

When the size of the ESP system's load on the utility power supply becomes a significant percentage of its capacity, a VSD can reflect large amounts of distortion back into the power system. When this situation becomes a problem, the Electrospeed Advantage VSD can be configured to operate in 12 or 24 pulse input mode. For this configuration, the user must enable and utilize the additional converter control outputs provided on the main circuit board. A 30° phase shifting transformer is required for each additional converter utilized. The phase shifting transformers are connected between the input power line and the appropriate converter input terminals. Using this type of configuration can yield significant reductions in total input harmonic distortion. Contact the Baker Hughes Control Technology technical support group for further information. For the lowest THD, a 24-pulse option is also available.

ESP Output Mode vs. PWM Output Mode

NOTICE	Baker Hughes recommends the ESP mode (6-step) output or a filtered PWM output. Any variable speed drive with a PWM output must use a properly sized output filter when operating ESP's for longest equipment life.

The Electrospeed Advantage drive is capable of operating in both PWM (pulse-width modulated) mode and ESP mode (variable voltage, 6-step pseudo-sine wave). Although PWM operation can lower the total harmonic distortion reflected back onto the power supply system, the user must be aware of some potentially damaging effects due to this mode. Since PWM typically switches the full output bus voltage to the motor at a high carrier frequency, the ESP system, complete with output transformer and long power cable, can exhibit significant under-damped voltage ringing. This ringing of the output voltage can produce voltage spikes twice as high the normal operating voltage. These high voltage transient spikes can seriously degrade the insulation of both the cable and motor, and lead to premature equipment failure. If PWM operation must be utilized on an ESP system, the user should consider installing a properly-sized and configured-filter circuit on the drive output. A correctly sized filter can minimize the damaging voltage transients delivered to the ESP system, but at a cost of higher total electrical power consumption and heat generation. The Electrospeed Advantage VSD can also be configured to operate in a variable voltage PWM mode that can help to minimize the voltage transients when operating without an output filter. Whenever possible, Baker Hughes recommends that the Advantage drive is run in the ESP (six-step) mode to minimize equipment damage and increase run life. PWM mode can safely be used in surface motor applications where there is no output transformer and short motor power leads (less than 200 ft) are used. Contact Baker Hughes Control Technology technical support group for further information.

If PWM mode operation is preferred, Baker Hughes offers the Electrospeed Advantage in a filtered PWM configuration (FPWM™) which integrates a specialized filter for output waveform filtering, and a controller to manage the filter's operation. An added benefit of this system is that uptime of the system can be maximized by implementing a feature which will automatically switch over to ESP output mode if the output filter ever fails. This will guarantee safe operation of the ESP system while allowing the system to continue to operate until necessary repairs are made.

Please consult the FPWM setup guide to properly wire and configure the VSD for FPWM operation. The Electrospeed Advantage FPWM VSD has an improved interface for setting up the VSD via the graphical display interface (GDI). The wiring of the system must be given attention so as to assure proper operation.

Restart Time Delays

When the drive has shut down due to a non-lockout condition, the Advantage drive's operating system begins to decrement the restart delay timer. If the associated alarm/shutdown is still active at the end of the restart delay, the Advantage drive will wait in the off condition until the alarm is cleared. At this time, if no further alarms are active and the drive is configured for automatic restarts, the drive will attempt to start the motor.

Software Based Control Algorithms

The Advantage drive contains several built-in control algorithms designed to automate some commonly performed tasks. Each of these algorithms must be enabled and configured in the Advantage VSD, via the graphical display interface (GDI). A more detailed description is available in the operator's manual.

ILimit Operation for Gassy Wells

When operating in wells producing significant amounts of gas, the ILimit parameter can be used to help compensate. In this type of situation, set the frequency limit to the highest allowable operational speed. Set the ILimit parameter to cause the output frequency to be limited to the desired optimal value. Then, when gas is present in the pump, the motor load will decrease and the output frequency will rise until the ILimit or frequency limit parameters are reached. The slight increase in frequency will further compress the gas and help to move it out of the pump.

MaxPoint™: This feature will cause the drive to accelerate through a user selected range of frequencies over a selectable period of time.

MaxStart™: This routine is used to break free and start a stuck pump or motor. The drive will alternate between forward and reverse output power rotation until it detects the motor has broken free, and then switch to forward and accelerate as per normal.

8 Facts Regarding the Use of PWM Drives on ESP Systems

1. Phase-to-phase peak-negative to peak-positive transitions will occur if the carrier frequency is not correct for the power frequency.

The first consideration that must be given to a PWM 3-phase source is the relationship which should exist between the fundamental power frequency to be generated and the carrier frequency.

Each phase is generated with a carrier frequency that is pulse width modulated in accordance with a sine wave at the power frequency. Since a motor operates on the phase-to-phase voltage, it is important to consider what happens from phase to phase. Specifically, the pulses on each phase need to be appropriately timed to prevent phase-to-phase output transitions which switch from the negative peak to the positive peak. If this occurs, the voltage transition that enters the cable is twice the amplitude of that produced on any one phase, which immediately doubles problems due to impedance mismatch between the cable and the motor at the pump. This mismatch is severe and practically doubles fast rise time voltage transitions at the end of the cable.

Following a simple rule will prevent this problem. The rule is, only use carrier frequencies which are multiples of 1.5 times the power frequency being generated. This yields phase-to-phase voltages that always transition between zero and the minus peak (or zero) and the positive peak—the smallest allowable carrier frequency resolution that will avoid the problem.

Careful examination shows the carrier frequency is removed from phase-to-phase voltages when this rule is followed.

2. The carrier frequency cannot be tuned to prevent high motor voltage peaks with reflection cancellation.

A very brief calculation shows this would require switching frequencies beyond practical with current technology, even if it could be accomplished. In fact, any time a fast rise time pulse enters the cable it will be nearly doubled at the impedance mismatch point between the cable and motor.

Consider a piece of cable with the motor end open as an example (the motor inductance causes the motor end to appear open to fast rise time steps). If a voltage step is introduced at the source end (allowing that the cable slows the propagation to 0.4 c, where c is the speed of light) then the step will traverse a 10,000 ft cable down and be reflected back in 5.1 usec. This means the source must be ready to switch in the opposite direction in 5.1 usec, which would correspond to a half cycle, hence the carrier period would be 10.2 usec, corresponding to a 9,821 Hz carrier. This does not solve the problem. In fact, it makes the problem worse. The pulse doubled in amplitude when it hit the motor end of the cable and was reflected back. The instant it returns the source switches to the opposite level in attempt to cancel the reflection, another wave propagates down the cable. The motor end of the cable was left at double amplitude and the new level coming down the cable is zero. Therefore, when it arrives a double amplitude step is impressed at the open end, which is then doubled. The open-end voltage then quadruples amplitude in the opposite direction (twice the new step). The process would continue to increase in voltage, if the cable was lossless, until the insulation finally broke down. Cable losses cause the end step to not quite double; hence a limit is eventually reached. The actual open-ended cable resonant frequency is lowered below 9,821 Hz by the cable losses even for an open-ended cable.

Although there are no frequencies which can cancel the reflections, there are some which will lessen the effect and can be selected. If a frequency which corresponds to the travel time down one length of the cable (twice the above frequency) is chosen, the behavior is as follows: at the point the first step reaches the end of the cable, the source switches back, setting up a wave which steps down to zero moving into the cable. At the same time, a double amplitude wave begins traveling back from the open end. These meet in the center and tend to cancel one another. The result is 2*step-step=step. Therefore, the center of the cable goes to amplitude 1*step, which propagates to each end. At the instant the new amplitude reaches the source, the source will be ready to switch back to exactly that level, no current flows and the voltage will be stable. At the same time, the new level reaches the open end, which is at 2*step and attempts to move it back to 1*step. The voltage step is then doubled, which moves the open end to zero. This zero begins propagating back to the source and arrives at exactly the time that the source switches back to zero. Again, there are no current flows and the state is back to where it was originally- both ends at zero. It should be noted that the source end is still pulsing at one time the step amplitude while the open end is pulsing at two times the step amplitude. The frequency required to do this is 19,642 Hz for 10,000 ft of cable. If the cable is shorter, the required frequency increases.

Other frequencies will alternately miss and cause the propagation energy to add to it, or subtract from it, and cause the voltage at the open end to increase and decrease with some beat frequency. The peak amplitude will depend upon how many reflections constructively add before destructive phasing occurs, which will vary with the carrier frequency.

The above is true for constant duty cycle square waves at the carrier frequency. In actual power generation, the duty cycle is constantly changing to produce the embedded sinusoidal power frequency. Consequently, there is no frequency which can always provide optimum behavior of double voltage at the open end.

Another approach to this argument is to use a PWM frequency low enough to allow the reflections to propagate back and forth until they die out before another pulse enters. But, this introduces power frequency harmonics due to the low pulses-per-cycle numbers of the power frequency. In fact, if this approach is used, a stepped waveform makes more sense since it never makes a full amplitude step.

3. High motor peak voltages cannot be avoided by tuning the carrier frequency to avoid system resonance.

In actual practice, the reflection phenomenon is overshadowed by system resonance (although the former never goes away). The system will behave as a resonant system at a frequency lower than the cable reflection resonance. The actual frequency is primarily controlled by the cable total inductance and capacitance and the percentage impedance (%Z) of the transformer. In fact, if all the cable capacity is grouped together as one capacitor, and an equivalent series inductance is calculated from all system inductors, the resonant frequency can be calculated. It is imperative the system not be driven with any energy near resonance because the resonant system is a high Q system. A resonant circuit will have a voltage gain approximately equal to the Q at the resonant frequency (e.g., with a Q of 20 and an excitation voltage of 1 kilovolt –20 kilovolts at the motor would not be unusual). To avoid this, it is vital that one understands which frequencies are generated by a PWM waveform. .

A 3-phase PWM waveform produces frequency groups which are centered on the carrier frequency and each harmonic of it. These frequencies are the sum and difference of frequencies between the carrier and the power frequency being generated. For example, if the carrier is 1,000 Hz and 50 Hz power is being generated, there will be frequencies produced at 950 Hz and 1,050 Hz, 900 Hz and 1,100 Hz, and so on. The third multiple of 50 will be absent as will other triples, and the strongest will be the second (unless the aforementioned rule is not followed, which will cause the carrier to appear and be the strongest). In the first group, the amplitude of each will decrease until they are insignificant by about the twelfth harmonic. The frequencies surrounding twice the carrier will all be of lower amplitude but they will not decrease in amplitude as quickly, giving a wider envelope.

With each harmonic of the carrier, the envelope will get smaller but broader until finally they overlap the previous envelope. Before the envelopes overlap, there are regions of frequencies between the carrier harmonics where no energy is generated.

In order to avoid system resonance excitation the carrier must be chosen so that the system resonant frequency is between the harmonics of the carrier.

This means:

$$fr = \frac{3}{2} fc, \frac{5}{2} fc, \frac{7}{2} fc, \ldots$$

or solving for fc:

$$fc = \frac{2}{3} fr, \frac{2}{5} fr, \frac{2}{7} fr, \ldots$$

Where fc=carrier frequency

fr=system resonant frequency

In actual practice, the midpoint is not the ideal point since each envelope broadens, rather than 2/3, 2/5, 2/7, the best position is $\frac{1}{\sqrt{2}}, \frac{1}{1+\sqrt{2}}, \frac{1}{2+\sqrt{2}}, \ldots$

An example of all this is:

Figure 29: PWM spectrum, 3 kHz carrier generating 50 Hz

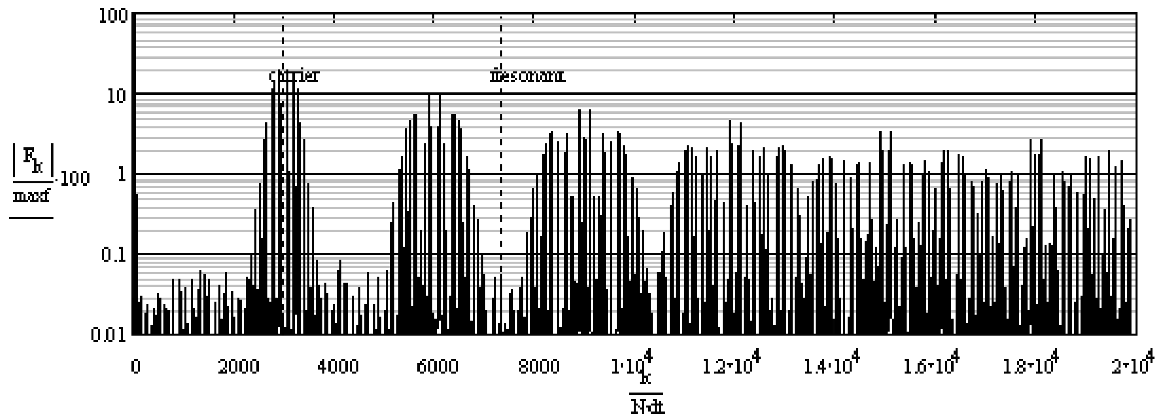
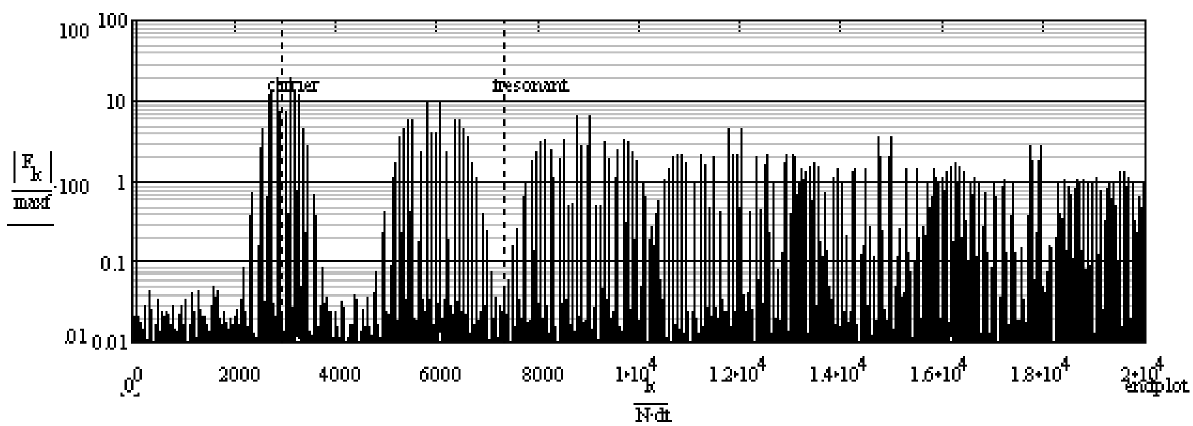


Figure 8 is the spectrum of a PWM drive generating 50 Hz with a carrier frequency of 3 kHz. This is the nearest multiple of 75 to 41.4% of the system resonant frequency (7,358 Hz). The system is a 180 hp, 1,580 V motor with a 6.5% 500 kVA transformer and 5,000 ft of number 1 cable. The cable is 140 uH and 0.075 uf per kft.

Assuming the system resonant frequency is accurately determined, an optimum carrier frequency can be selected. Remember the carrier frequency must move in increments of 1.5 times the power frequency or double amplitude transitions will emanate from the drive. Therefore, the optimum frequency cannot always be precisely generated.

In the above example, the target value was 3,012.68 Hz. However, since the valley between the second and third envelope is fairly broad, the slight shift is insignificant. If a higher power frequency is generated the position becomes more critical as can be seen from **Figure 9**, which is the same system with 60 Hz being generated. The frequency step is now 90 Hz, making it more difficult to optimize the carrier position.

Figure 30: PWM spectrum 2.97 kHz carrier generating 60 Hz power

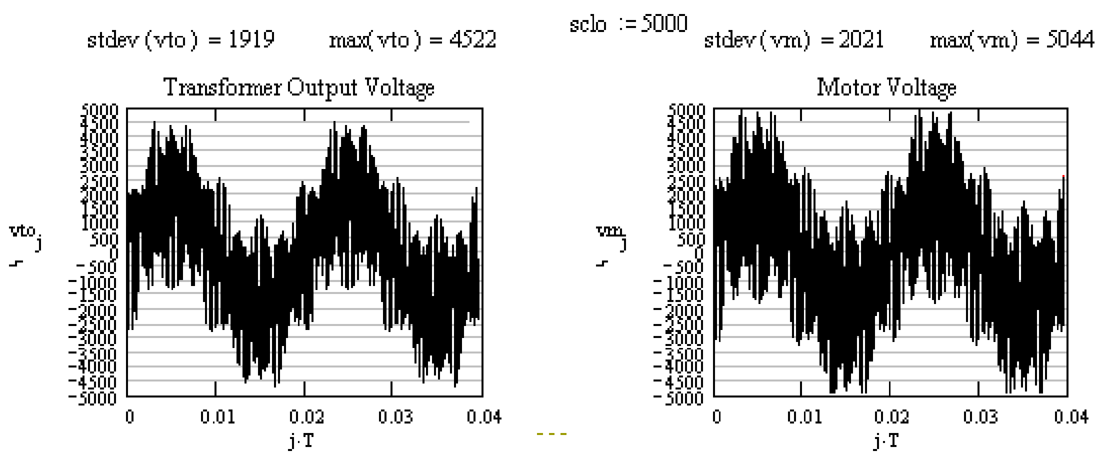


Note in Figure 9 the width of the no energy region about the system resonant frequency (valley between carrier harmonics 2 and 3) has narrowed. As the generated frequency goes higher, the energy from the second and third envelopes will overlap and the system resonance will be excited. In many cases, shorter cable length or lower transformer impedance will be used, both of which result in a higher resonant frequency. When the resonant frequency reaches a certain point, it must be positioned between the third and fourth envelope because a high enough carrier to keep it between the second and third is not practical due to switching losses. The low energy region between envelopes three and four is very narrow and unfortunately, overlaps in many applications, hence no good operating point can be achieved.

It should be noted that the voltage peaks at the motor will always be higher than at the output of the transformer. This is due to reflections at the motor terminals because of impedance mismatch (as stated before, reflections never go away completely), and is essentially independent of the voltage drop on the cable at the power frequency. As the transformer impedance is lowered, the transformer output voltage peaks decrease, but the motor voltage peaks tend to increase. Even when an optimum carrier frequency is used, the motor peak voltage is always higher than the transformer output peak voltage.

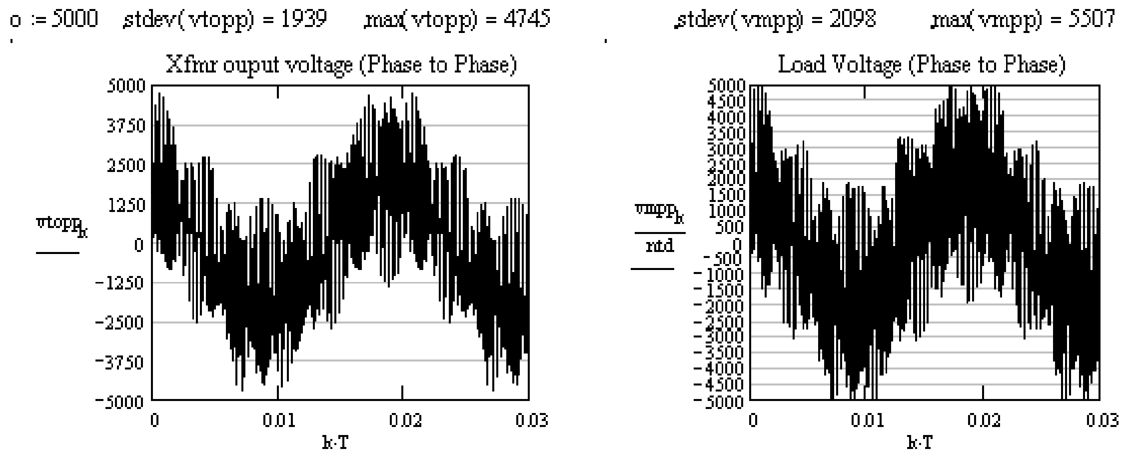
Care must be taken in modeling these systems, single lumped circuit analysis will show a difference between transformer end and motor end voltages, but it will always be below the actual. To properly analyze the system, cable characteristics must be analyzed with at least ten lumped value sections. The more sections the more accurate the result. An example of combining all cable parameters into a single LRC T section is shown in **Figure 10**.

Figure 31: 3 kHz carrier generating 50 Hz power, single lumped value model



If a cable model is used with the cable divided into 15 sections, the result is:

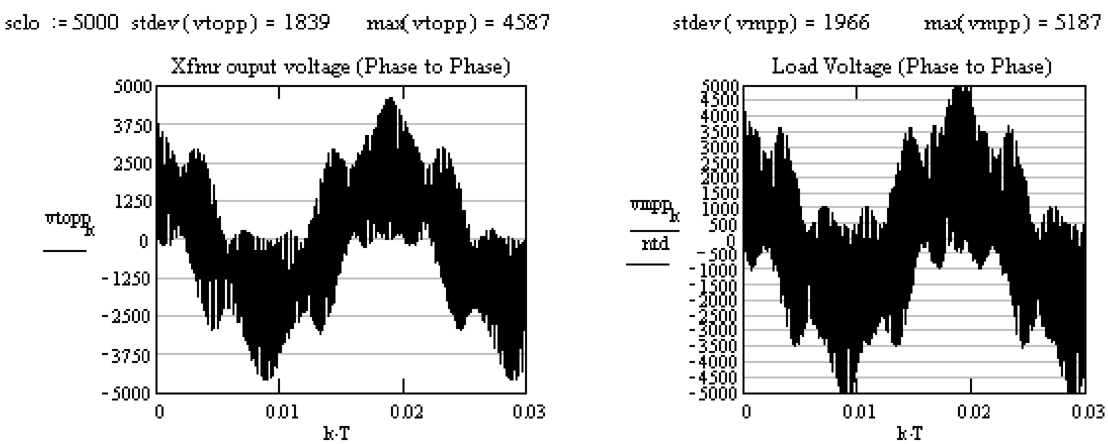
Figure 32: kHz carrier generating 50 Hz power, cable modeled with 15 sections



Note the 15 section cable model shows a higher motor voltage by nearly 500 volts.

If the resonant frequency is placed between the first and second envelope (and moved about to find the minimum voltage point), the best operating point is a carrier of 4,875 Hz.

Figure 33: 4,875 Hz carrier generating 50 Hz power, cable modeled with 15 sections

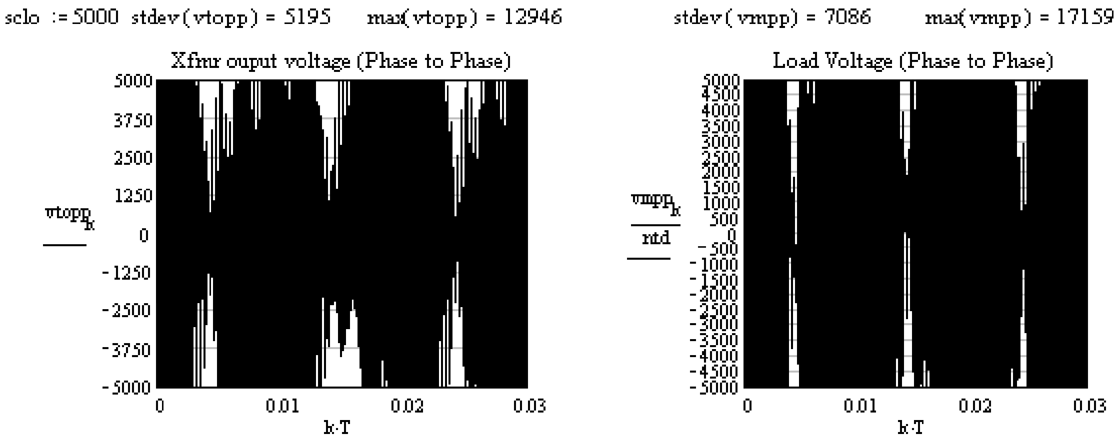


In all of the above, 1,315 volts RMS at 50 Hz is generated and utilized by the motor. **Figure 11** represents the best that can be achieved with a carrier around 3 kHz. **Figure 12** is the best which can be accomplished positioning the resonant frequency between the first and second envelope. As can be seen, only a few hundred volts-lower-motor voltage is achieved.

For a drive without a transformer, the situation actually gets worse due to higher rise times into the cable (no transformer impedance to slow it), which increases the reflection problem and raises the resonant frequency to very close to the cable self-resonance.

If the carrier is 1/4, 1/2 or 3/4 of the resonant frequency, a harmonic of the carrier will be centered at the resonant frequency with disastrous results. Here is an example of a carrier frequency at 1/2 of the resonant frequency (the scale is left the same to illustrate the magnitude change).

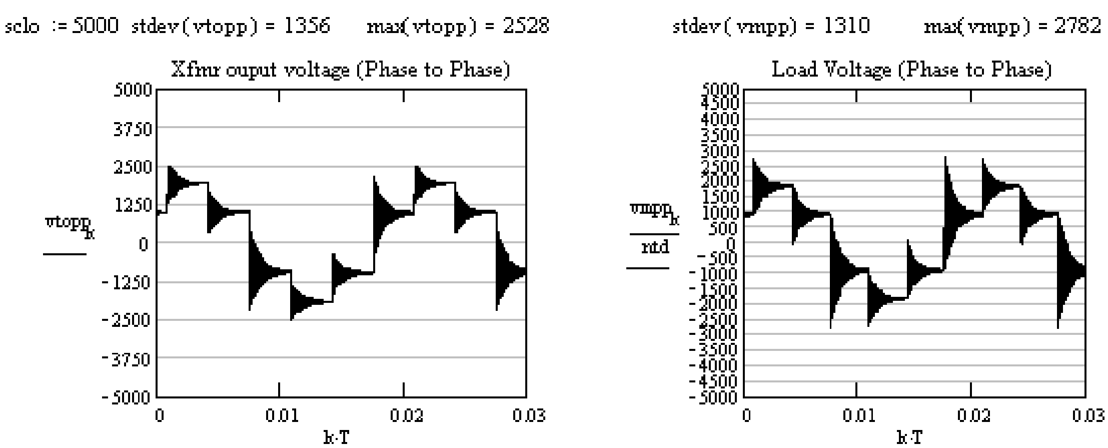
Figure 34: 3,675 Hz carrier generating 50 Hz power, cable modeled with 15 sections



In summary, a filter should always be used when PWM power generation is employed. Even the best positioning of the carrier frequency will result in motor voltages that overstress insulation and eventually cause a failure. This study was performed for the generation of 1,315 volts RMS phase to phase at 50 Hz. Many applications must use higher voltages than this and will produce voltages that far exceed insulation ratings even for the best carrier frequency positioning. Poor carrier frequency selection will produce voltages that rapidly destroy equipment.

As a point of reference, the same system driven by a 6-step wave yields the following waveforms. Note the much lower peak voltages.

Figure 35: Six-step generating 50 Hz power, cable modeled with 15 sections



Voltage Stresses

The combined demands of high voltage and limited space in submersible equipment raises the issue of voltage-related failures to a significant concern. As stated earlier, a VSD can act as a buffer between the power system and the downhole equipment by isolating it from random system transients. However, all power inverters, when applied to a submersible system have the potential to generate higher peak voltages than when the system is operated from a sinusoidal voltage source. This is due to the fact that inverters are inherently digital in nature, rather than analog (the output can only change in discrete voltage steps and the transition from step to step happens quite rapidly). When these square waveforms are applied to the complex impedance of the downhole system, the natural response is a damped sine wave. The peak value, resonant frequency, and decay rate of this sine wave is determined by the complex impedance of all of the equipment connected to the output of the VSD.

Even though this ringing is a normal response of the downhole equipment to the VSD output waveform, it can become a problem under certain conditions. On a 6-step drive, the ringing has time to decay to zero between each vertical edge of the waveform. However, on a PWM waveform the vertical edge of the VSD output waveform can occur at just the right instant to add to the ringing from the previous vertical edge. Under the worst conditions, this effect can produce peak voltages in excess of two times the applied peak voltage and can occur many times per cycle. The two main considerations are the magnitude of the voltage stresses and the frequency of repetition. The rise time of the overvoltage stress greatly impacts the potential for ringing. In fact, it is the repetitions, along with the rise time, that have the most potential for insulation damage.

This problem arose in the industrial market a number of years ago when problems were documented with as little as 100 ft of cable between the drive and the motor. Manufacturers have since developed a number of methods to deal with the ringing. When applying these methods, it is important to understand their limitations and drawbacks. The simplest method is to add series inductance between the VSD and the load. This can slow the rise time of the voltage waveform applied to the downhole equipment. However, unless very large inductors are used, the overall effect may be minimal due to the relative impedance of the inductor to the overall system impedance. Most other methods involve some type of filter applied to the high voltage side of the step-up transformer. These filters can consist of L-C, R-C or R-L-C combinations or just capacitance. A large enough R-L-C filter could completely smooth out the waveform into a perfect sinusoid. However, within the cost constraints of most applications, the filter will only be large enough to reduce the ringing effects by some percentage.

Mechanical Wear

Decreased motor bearing life has been noted in units being operated from inverter supplies. This is the result of increased bearing wear due to a process known as electric discharge machining (EDM). Induced shaft to stator voltages create currents which remove bearing material as they flow. The effect is more pronounced in long axial machines. The phenomenon is also noted in motors fed from a utility source. However, PWM inverter-fed surface motors have been shown to produce fifteen times greater shaft–to-stator voltage potential compared to a motor operated across the line. It is these voltages that produce currents in the bearings and cause the electric discharge machining effects.

Variable Speed Drive Motor Control

While it is not in the scope of this document to discuss VSD control algorithms, it is beneficial to understand how the various control schemes affect the overall system performance. Most of the VSDs have control methods which can be loosely grouped into one of three classifications: 1) voltage control 2) current control, and 3) flux or vector control. There is typically an outer control loop that determines if the motor is operating at the correct rpm and one or more inner loops with the innermost being type 1, 2, or 3 as listed above. In methods 1 and 2, the process is just as the name implies. The desired motor terminal voltage (or current) and frequency are determined by the outer loop(s) and then regulated to some tolerance by monitoring the actual motor currents and/or voltages. The response time of these two methods is somewhat limited by the topology. For instance, in a variable voltage inverter, the maximum rate of change of the output voltage is affected by the choice of DC link components and in a PWM inverter; the response time is limited by the choice of switching frequency. However, in both cases, the ultimate limit to the response time is the motor itself. An induction motor is by nature very oscillatory in its response to step changes in terminal voltage or loading. Because of this, the time required to stabilize after a change in load can be quite long (particularly for large diameter surface motors with high inertia).

An ESP motor is drastically different than a surface motor, therefore the control algorithms must be adapted to accommodate such things as very small rotating inertia, long cable lengths, loads that change (but not near as quickly as in some industrial applications), step up transformers (which can be especially problematic if the VSD motor control algorithm needs an ID run as many industrial VSD’s need) and so on.

Knowing what is happening in the motor is not the same as controlling it, however. Because of real world parasitic elements in the motor, (e.g., leakage inductance and conductor resistance) sudden changes in the motor load will cause momentary changes in motor flux and torque without some form of compensation. This is where the differences between a surface motor (with its larger rotating inertia) and a submersible motor become quite evident. The VSD must try and settle gyrations in the motor to establish a steady-state in the face of changing loads.

The Advantage VSD uses a specialized vector control algorithm which accommodates for these differences, yet is forgiving for improper or inaccurate setup data. By utilizing a motor model, which is described in the motor nameplate data and unloaded current, motor torque can be calculated in less than one (electric) cycle. This algorithm is described as real time torque command in the Electrospeed Advantage VSD.

9 Data Recording Capabilities of Advantage Control Products

The Advantage drive provides two methods to locally record operational data. The preferred storage / retrieval method is via the USB memory device port. The second method uses compact flash memory cards and is similar to the GCS drive data logging functions. This section of the manual will provide insight into the type and frequency of data recorded as well as information pertaining to the retrieval, formatting and displaying/graphing of the data.

USB Memory Device

The Advantage Electrospeed historical data gathering system was designed to provide a number of improvements over the GCS logging capability. The improvements to the system were made based on numerous requests, field feedback and comments over the life of the GCS products. The system incorporates a number of key goals:

1. **Automatically set up and enabled**, negating the need to configure it manually. This came about partly from competitor pressure but also because we had many instances of failures where the local personnel had not set up logging prior to the incident and had no data to diagnose problems with.
2. **Endless logging**. This simply means that we log most system parameters 24-7 until local memory is consumed and then remove the oldest data to make room for new logging. This ensures the previous 3 to 6 months of data is always available for troubleshooting and diagnosis. The log files are arranged in a folder tree with an individual folder for each day the system is powered up.
3. **Preserve Daily Event & Shutdown History**: Any events or shutdowns which occur each day (up to the maximum 255 events or 99 shutdowns) will be saved alongside the log data for that day. This essentially means that the event and shutdown history are also available from several weeks to months previous. The digital ampchart is stored to permanent storage every week, again, for months of time.
4. **Maximize data**. Our goals to have high resolution historical data always available do mean dealing with much more source data. For this reason, we needed to change to a binary format to conserve space and provide some compression. As was pointed out, our log files are approximately 1.5 MB in size per day in a binary format. The similar file size in .CSV (text based format) as you point out would be 20 MB or more and files of that size would be unmanageable when transferred over USB from the drive.
5. **Log only the important data changes**. We have implemented 'deadbanding' for all the parameters in an attempt to balance the number of samples we actually record. Though the data is evaluated every second, new data is only recorded if it changes notably from the previous recorded value. As a result, any parameters which never change in value are recorded only one time.

The Advantage system is different from the GCS though, and requires some changes in the management of the data files. This document will attempt to highlight the similarities and differences between the GCS and Advantage Systems, and detail how the various Advantage historical files can be managed by the user.

Historical Logging Summary

The following list summarizes the capabilities of the historical data and configuration features for the Electrospeed Advantage series

- 254 Most recent System events
  - Including startup, shutdown, power up, parameter change, alarm condition etc.
  - Stored in non-volatile memory (retained over power failure)
  - Events for the day are recorded every midnight.
  - Copied to USB Door drive during a 'Get Historical Data' operation.
  - Saved to Compact Flash on demand
  - Visible on Display menu
- 99 Most recent shutdowns
  - Included shutdown cause, volts, amps and analog inputs @ shutdown
  - Stored in non-volatile memory (retained over power failure)
  - Shutdowns for the day are recorded to the SPM every midnight.
  - Copied to USB Door drive during a 'Get Historical Data' operation.
  - Saved to Compact Flash on demand
  - Visible on Display menu
- Digital Ampchart
  - Emulates 7 day paper recording amp chart
  - Stored in non-volatile memory (retained over power failure)
  - Ampchart is updated each Sunday night at midnight.
  - Saved to Compact Flash on demand
  - Copied to USB Door drive during a 'Get Historical Data' operation.
  - Last week of data visible on Display menu
- Endless Data logging
  - 61 system parameters automatically configured
  - Evaluated and sampled once each second.
  - Data compressed and stored in real time (.dat file type)
  - Retains all data up to moment of power failure
  - No user setup required
  - 3-6 months retention of log data
  - Endless logging with oldest data removed each week to make room for new data
- User Configurable Logging
  - Stored directly to Compact Flash (requires Compact Flash be enabled)
  - User selectable 24 items from list of ~200 system parameters
  - Duration is once per second
  - Dead band requires sample to change by 2% of previous value before being recorded to disk. Smart dead banding features in future versions.
  - Similar 'endless' features remove oldest data to make room for new data.
  - Requires main cabinet door to be opened for insertion / removal
- Drive configuration / setup
  - Drive setup automatically saved within 15 minutes of parameter change, does not require drive to be shut down.
  - Drive configuration retained on personality module and will automatically reload set points when software is upgraded or system board is replaced.
  - Copied to USB Door drive during a 'Get Historical Data' operation.
  - can be saved or loaded via the Compact Flash slot
- Firmware Updates

- Firmware updates can be loaded via the door mounted USB stick by following the software upgrade procedure.
- Updates can be loaded while the drive is running. Will be applied the next time the system is booted. Recommend someone on-site to apply the upgrades.

Automatically recorded parameters

The data logging subsystem is automatically configured to monitor a number of system parameters once per second and record changes if the most recent value exceeds the last recorded value by the indicated deadband. The list of parameters that are automatically logged is as follows:

Parameter	Deadband	
Output Frequency,	0.2	
Output IA,	1	
Output IB,	1	
Output IC,	1	
Output Volts,	1	
Motor Torque,	2	
Input Power Frequency,	0.2	
Converter 1 VAB,	5	
Converter 1 VBC,	5	
Converter 1 VCA,	5	
Voltage Unbalance,	2	/* % */
/* Heatsinks 2000/4000 */		
Heatsink 1 Temperature,	2	/* DEG C */
Heatsink 2 Temperature,	2	
Inductor Temperature,	2	
Ambient Temperature,	2	
/* onboard I/O */		
Analog Input 1,	3	
Analog Input 2,	3	
Onboard Digital Input 1,	0	
Onboard Digital Input 2,	0	
Onboard Digital Input 3,	0	
/* centinel I/O */		
Centinel Intake Pressure,	5	
Centinel Intake Temperature,	2.0	
Centinel Motor Temperature,	2.0	
Centinel Vibration X,	0.2	
Centinel Vibration Y,	0.2	
/* external I/O */		
Expansion I/O1 Analog Input 1,	2	
Expansion I/O1 Analog Input 2,	2	
Expansion I/O2 Analog Input 1,	2	
Expansion I/O2 Analog Input 2,	2	

Expansion I/O3 Analog Input 1,	2
Expansion I/O3 Analog Input 2,	2
Expansion I/O1 Digital Input 1,	0
Expansion I/O1 Digital Input 2,	0
Expansion I/O1 Digital Input 3,	0
Expansion I/O2 Digital Input 1,	0
Expansion I/O2 Digital Input 2,	0
Expansion I/O2 Digital Input 3,	0
Expansion I/O3 Digital Input 1,	0
Expansion I/O3 Digital Input 2,	0
Expansion I/O3 Digital Input 3,	0

/* first 5 of each RDCM point */

RDCM Device 1 Tag 1,	2
RDCM Device 1 Tag 2,	2
RDCM Device 1 Tag 3,	2
RDCM Device 1 Tag 4,	2
RDCM Device 1 Tag 5,	2
RDCM Device 2 Tag 1,	2
RDCM Device 2 Tag 2,	2
RDCM Device 2 Tag 3,	2
RDCM Device 2 Tag 4,	2
RDCM Device 2 Tag 5,	2
RDCM Device 3 Tag 1,	2
RDCM Device 3 Tag 2,	2
RDCM Device 3 Tag 3,	2
RDCM Device 3 Tag 4,	2
RDCM Device 3 Tag 5,	2

/* for diagnostics purposes */

Bus Volts,	2
PCM Fault Word,	1
DC Link Amps,	2
PCM Fault,	1
PCM Diagnostic 1,	1
Input KVA,	2
Power Factor,	0.02
Motor RPM	17
Set Frequency,	0.1

A log file is created for each day of operation and stored in a hierarchal tree organized by year, month, week and day. Each day a midnight, the log file is closed and event / shutdown history data for the day is stored in the same directory. Then a new directory is created to hold the historical data for the new day. The Digital Ampchart is stored in the directory tree every Sunday night at midnight.

The log data is retrieved via a USB Flash drive which can be inserted into the front of the drive. When a drive is inserted, a USB functionality menu will be displayed, allowing the user to ‘Get History’. When this option is selected, the system will prompt the user for the date range of data to be retrieved (The default will be the previous 2 weeks of data). Once accepted, the system will begin copying the data files from the internal storage to the USB drive inserted in the front of the VSD. The copy process can take several minutes to complete depending on the range of data selected.

The following diagram illustrates the hierarchy of file storage for the logged data:

```
WellData (root)
    Generic                                            ← Well Data will be stored here if no SiteID is set
    ESPonOilPlaform                                    ← Unique well Folder, based on SiteID
    ESPatCustomerX…                                    ← Other wells where data was gathered…
        2010-03                                        ← Folder for each year/month
        2010-04
            2010W24                               ← Folder for each Week of the Month
                10-6-13Ampchart.csv               ← Weekly Ampchart file, saved Sunday night at midnight
                10-6-13                           ← Daily Folder
                        10-8- ESPatCustomerX.dat  ← Daily Log file –binary encoded
                        10-8-31SDHist.csv         ← Daily Shutdowns recorded - compatible with GCS
                        10-8-31Events.csv         ← Daily Events recorded, max 254 - compatible with GCS
            Setpoints                             ← Drive setpoints, saved during a 'get history' operation
                ASC_Configuration_113015.txt      ← VSD Settings file
                ASC_Configuration_113015.md5      ← Error check file
```

Note that the hierarchy above is the tree that will be written to the USB stick. The internal storage does not include the well site ID level. The ability to store data from multiple wells in a common structure makes it extremely important that individual wells are all given a Site Id otherwise data from various wells will be intermingled in the Generic directory.

Changes to Data Logging Output Files

When implementing the concept of endless, auto-configured, logging of multiple system parameters, the system was dealing with a large number of data points at high sample rates. The CSV file format, being text based, is not very efficient in terms of file size. Additionally, the CSV file format presented problems for Excel if the number of samples recorded in one day exceeded the maximum number of samples (32000 or 64000 depending on Excel version). This meant that a large log file created on the GCS platform might not be fully loaded into Excel in many cases. For these reasons, we changed to a daily log file concept and also changed the output file to a packed binary format with a .DAT file extension.

Data File Conversion

The binary .DAT files created in the logging process can be converted to the traditional .CSV file format using a PC application titled "Advantage DAT Converter. Details of how to use this application can be found later in this document. In binary form, our log files are ~1.5 Megabytes per day. When expanded to CSV format, the files get as large as 20 MB or more because the .csv files are text based.

We are moving along the following path for use and manipulation of the log data:

- We have created a PC Based application to convert the binary .DAT files to a compatible .CSV format. The Advantage DAT Converter is available on Baker Hughes Direct for all employees. This tool is fairly easy to use and we are planning user enhancements going forward.
- We have expanded the capability of CentriMATION to load and graph up to 70 channels from the CSV converter log file.
- We have also worked with the developers of the CentriGraph tool to incorporate the data conversion function directly into that software so the conversion is relatively seamless to the user.
- We are planning future enhancements to the DAT converter tool to filter the data files, allowing the user to select only the data points desired as an additional way to reduce file size.
- A further enhancement would be to reduce the sample rate of the data when extracting to CSV format to further reduce the output file size.

Managing Large CSV Files

In binary form, our log files are ~1.5 Megabytes per day. When expanded to CSV format, the files get as large as 20 MB or more because the .csv files are text based. This is due to the large number of sampled data points, but also due to the 1 second rate at which we check for changes in data during the logging process. The most likely culprit, however, is the use of the “fill empty data samples” option which can be unchecked in the Advantage DAT converter to greatly reduce output file size, though compatibility with Excel graphing may be affected.

There are a couple other fairly simple solutions to manage the large CSV file size for transfer via email:

- Send the DAT file instead of the CSV file. This puts the onus on the receiver of the email to know about the DAT Converter and how to use it.
- All BHI computers have WinZip installed as a standard application. This allows us to easily Zip the CSV file before sending. Simply right click on the file and select “Add to filename.zip”. This operation can compress CSV files from 20 MB to 541 KB in size.

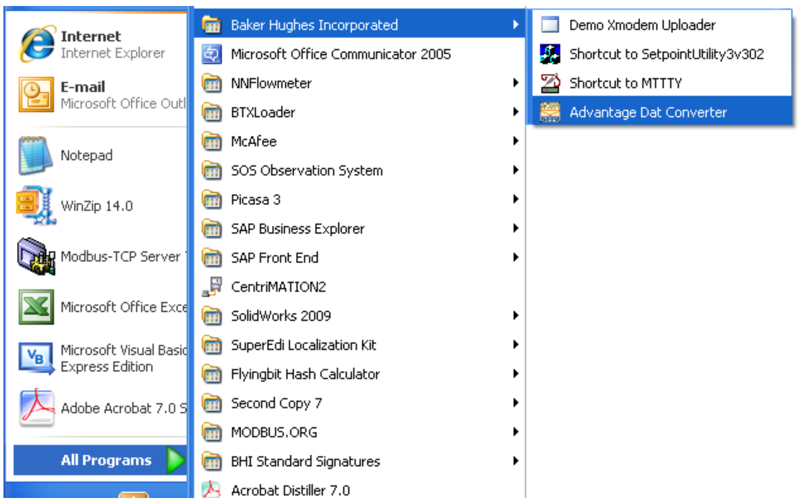
The Advantage DAT Converter

The Advantage DAT converter is a simple PC utility that allows the user to convert any of the .DAT data files created daily by the Advantage logging system to a CSV format consistent with GCS log files.

The Advantage DAT Converter is available on the Baker Hughes Direct and the Advantage Regional Support Workspace in the Software / PC Applications folder.

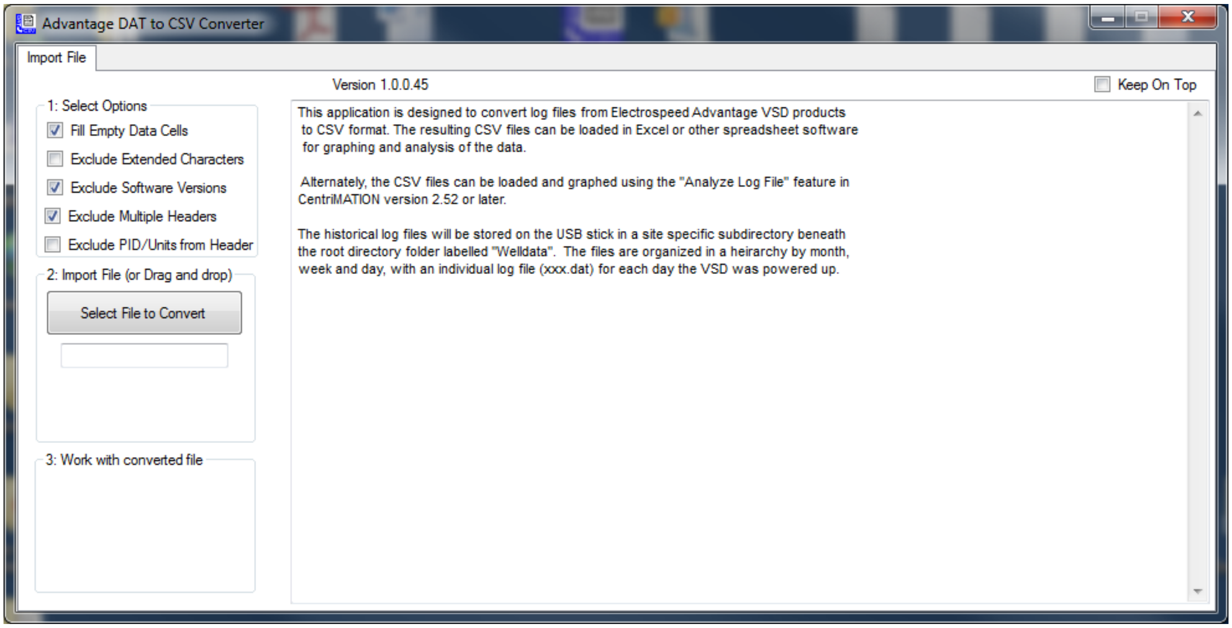
Installation

As of the Advantage DAT Converter version 1.0.0.45, the application is available as a simple executable and does not require any installation. The utility can then be run by double clicking the icon.



Using Advantage DAT Converter

The Advantage DAT Converter main menu is shown below:

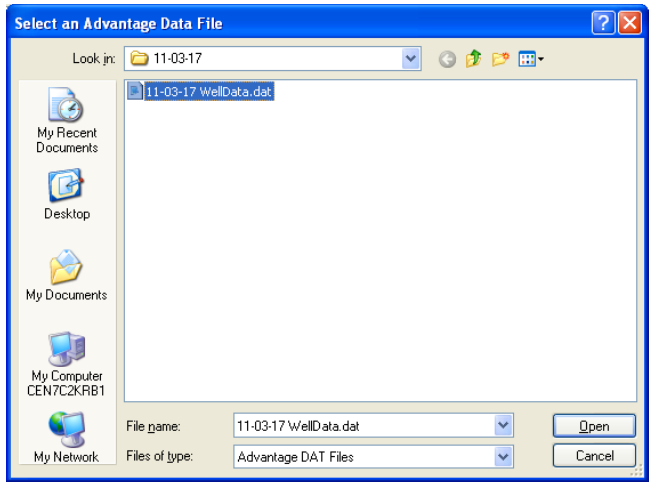


The Options available are as follows:

- Fill Empty Data Cells: (Default: Checked) Advantage logging utilizes dead band settings which will prevent a specific parameter from being logged until the value in the parameter changes by a significant amount. This will leave ‘empty holes’ in the sample data where the previous value at a given time is the same as the last sample. This saves space on disk but can make graphing in Excel more difficult. Selecting this option will copy the last known value into the CSV file for spreadsheet use. This will also increase the size of the CSV file significantly. If you intend to use CentriMATION to view and graph log data, this option is not necessary as CentriMATION will automatically fill empty cells when it imports the CSV files.
- Exclude Extended Characters: (Default: Checked) This option will prevent Unicode characters from being converted to the CSV format (which is ascii and does not support Unicode)
- Exclude Software Versions: (Default: Checked) The current software version numbers are stored in the log file whenever logging is started. This option will prevent the Software Version information from being written to the output file. This information will typically confuse Excel and CentriMATION with respect to column headers. If it is necessary to know what versions of software generated the log file, uncheck this option and review the CSV file in a text editor.
- Exclude Multiple Headers: (Default: Checked) Each time logging is started, a new header file listing parameters names and units will be written. Any headers in the middle of the log file should be consistent over time and will confuse graphing tools so they are excluded by default.
- Exclude PID/Units from Header: (Default: Not Checked) The standard .csv log file has column headers in three text lines: 1. Column Descriptions, 2. Point References,

3. Units. Checking this option will prevent the Point References and Units from being saved to the CSV file.

Converting a File:



- To convert a given DAT file, set the options that are desired (defaults for most applications) and click the *Select File to Convert* button.
- Then insert the USB stick with the log data and/or use the file selection dialog to locate the file to be converted. (Note: only files of type .DAT will be visible in the file dialog)

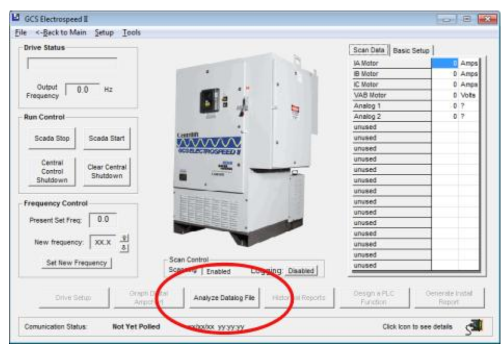
The progress of conversion will be displayed in the main DAT Converter window. (Example depicted in the earlier snapshot. The converted .csv file will be saved in the same directory as the original file is located.

Alternately: The DAT Converter supports Drag-And-Drop operations. If a .DAT file is dragged from a file folder and dropped onto the main program window.

Once the Conversion is complete, the two buttons at the bottom left become visible.

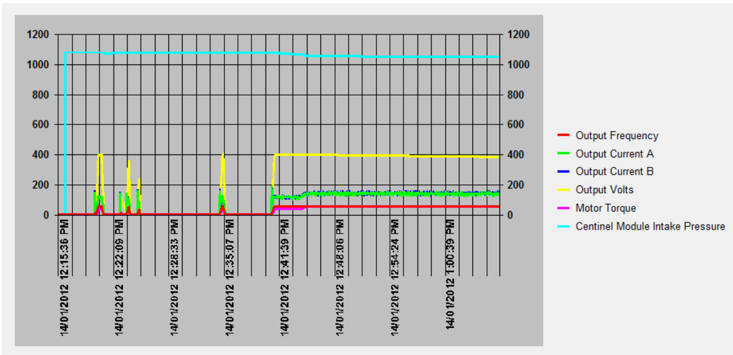
- Explore Last Conv Directory: Will open the directory that contains the file that was last converted
- Open Last Converted File: Will launch the Windows application that is tied to .csv files (typically Excel) for the purpose of viewing / editing the file.

Graphing the DATA



Once in CSV format, graphing the log data is basically identical to graphing operations completed with Electrospeed GCS log data. This can be completed using the charting capability built into Excel or using the CentriMATION *Analyze Log* file button found on the GCS Drive page. Due to the increase in the number of horizontal columns from 24 to 61 in Advantage, CentriMATION has been updated to version 2.64. Other enhancements include the ability to change the background color, the pen colors and the addition of a fine scroll control. The latest version is available on the Advantage Regional Support site but will shortly transition to the standard Baker Hughes Software pages once a full release package is created. CentriMATION graphing capability is detailed in the CentriMATION manual which can be found on Baker Hughes Direct.

NOTE: The functionality of the Advantage DAT Converter has also been integrated into the new *CentriGraph* utility maintained by Gennady Afanasyev in the Russian Region.



PC CompactFlash Card

The Advantage drive also provides a compact flash (CF) memory card slot and maintains all the CF functionality of the GCS Electrospeed drives. This memory card interface can be used to copy and store data-logging records; amp chart readings, graphic screen shot captures, and drive setup configurations. Baker Hughes recommends using the USB memory interface for all data transfers since USB does not require the user to open and access the high voltage compartment.

Inserting the CompactFlash Card into the Graphic Display

Orientation The compact flash card slot is located on the interior of the cabinet door with the Advantage graphic display mounted flush to the exterior door.

Note: The compact flash card could be pushed into the slot incorrectly if excessive force is used. The general rule is that if the card slides more than 3/4 of the way into the slot without any major obstruction, it is oriented correctly. If any problems exist with the card, an error message will be displayed

.

Troubleshooting CompactFlash Card Problems

The following question and answer guide should be used as a first step in solving CompactFlash card problems with the Advantage display.

Problems Using the CompactFlash Card with the Advantage Display

I insert the CompactFlash card into the Advantage display and get a message that says: disk error or file access error.

The Advantage CompactFlash card software is designed to operate through power loss situations. There is, however, a small chance data file corruption could occur while data are being written to the CompactFlash card. Should a power fluctuation or loss occur at precisely the same time as a write occurs, the data file size information could be corrupted. In most cases, only the last few samples of actual data may be lost. To correct this problem, simply insert the CompactFlash card into the Windows computer and run the Scandisk utility (found in start → programs → accessories → system tools). This utility will likely indicate some file size errors. Allowing Windows to fix the errors will most times fix the corrupted files.

If the previous steps do not fix the problem, the user may attempt to format the flash disk from Windows. This is accomplished by selecting the correct CompactFlash disk from the My Computer explorer window and then selecting the format command from the file menu.

IMPORTANT: Ensure the disk selected for formatting is the correct CompactFlash disk, not any other disk in the system. If the incorrect drive is selected, the computer's primary hard drive could be deleted.

I insert the CompactFlash card into the Advantage display and get a message that says: invalid card or disk error.

The Advantage CompactFlash card slot is designed and programmed following the CompactFlash card ATA standard and, as a result, it should be compatible with all ATA style CompactFlash cards. Incompatibilities may still exist with some manufacturer's cards. We are actively testing CompactFlash cards from several manufacturers for compatibility and reliability. If the CompactFlash card in use shows these types of errors, there may be a compatibility error. Please report the manufacturer, type, part number and size to Baker Hughes Control Technologies for investigation.

Alternately, the CompactFlash card in question could be damaged or require reformatting. See the answer above for steps to try reformatting the card.

Problems Using the CompactFlash Card with a Windows PC

When I insert my CompactFlash card flash disk into the CompactFlash card slot, no new drive appears in the My Computer explorer window, why not?

Many new computer systems have almost their entire interrupt request lines (IRQs) used with various hardware such as sound cards, CD-ROM drives, serial ports parallel ports, USB ports, etc. When the CompactFlash card ATA Flash disk is inserted, it requires a free IRQ to perform data transfers to the computers processor. There are only a limited number of IRQs available in a computer system; if they are all in use when the CompactFlash card is inserted, Windows will not be able to add the new drive to the system. On many laptops with multiple compact flash cards, this can be alleviated by removing any other CompactFlash cards which are plugged in, such as modems or LAN adapters. Consult your local information services personnel for other ways to free up system IRQs.

When I try to open the log.csv file, my spreadsheet software prompts me with a dialog box which indicates the file was partially loaded. What does this mean?

This error was found to occur due to an invalid DOS format, which corrupted the file allocation table. The solution is to reformat the CompactFlash card in Windows, which corrects the file structure and boot record. This is accomplished by selecting the appropriate CF memory card from the My Computer explorer window and then selecting the format command from the file menu.

IMPORTANT: Ensure the disk selected for formatting is the correct CompactFlash disk, not any other disk in the system. If the incorrect drive is selected, the computers primary hard drive could be deleted.

Note: Formatting the CompactFlash card will result in the loss of all data that was logged to the card. If there is critical data on the card, it can be retrieved with special disk utilities.

Please use the information found below to contact one of our support personnel.

If these steps do not provide a solution, please contact the Baker Hughes Control Technologies group and have the following information ready to facilitate problem resolution:

- The software versions loaded in the Advantage devices (located in the SCADA & System & Security menu in the Software Rev Num submenu)
- The manufacturer's name and type of CompactFlash card along with a part number and size
- A list of symptoms or error messages appearing on the display

10 Schematics

Introduction

The Electrospeed Advantage variable speed drive (VSD) is represented electrically by two different sets of schematic drawings: the control schematics and the power schematics.

The control schematics provide a black box view of the power topology and focuses on the details of the control circuitry interconnections as well as the various available options.

The power schematics primarily focus on the details of the power topology (inverter and converter sections) but also provide detail to other connections that have a one-line representation in the control schematic.

Note: The schematics provided herein are for reference only. Refer to the Baker Hughes document system for the most recent revision.

Control Schematic Diagrams

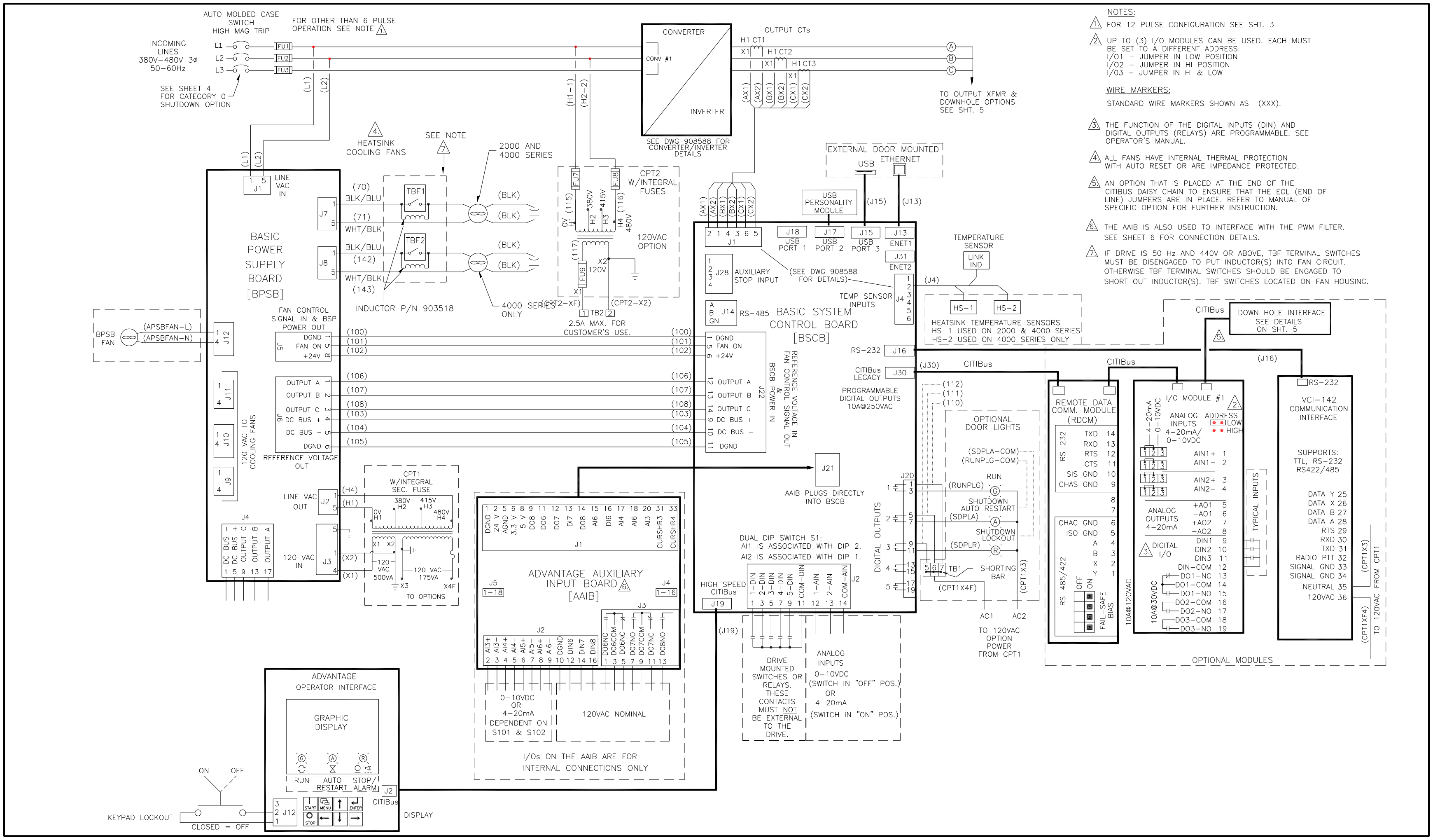


Figure 36: ADVANTAGE 2000/4000 NEMA 1 6-PULSE, 12-PULSE ALL STANDARD OPTIONS
Drawing reference number-908587, sheet number-2, revision-A, revision date: 12 June 13

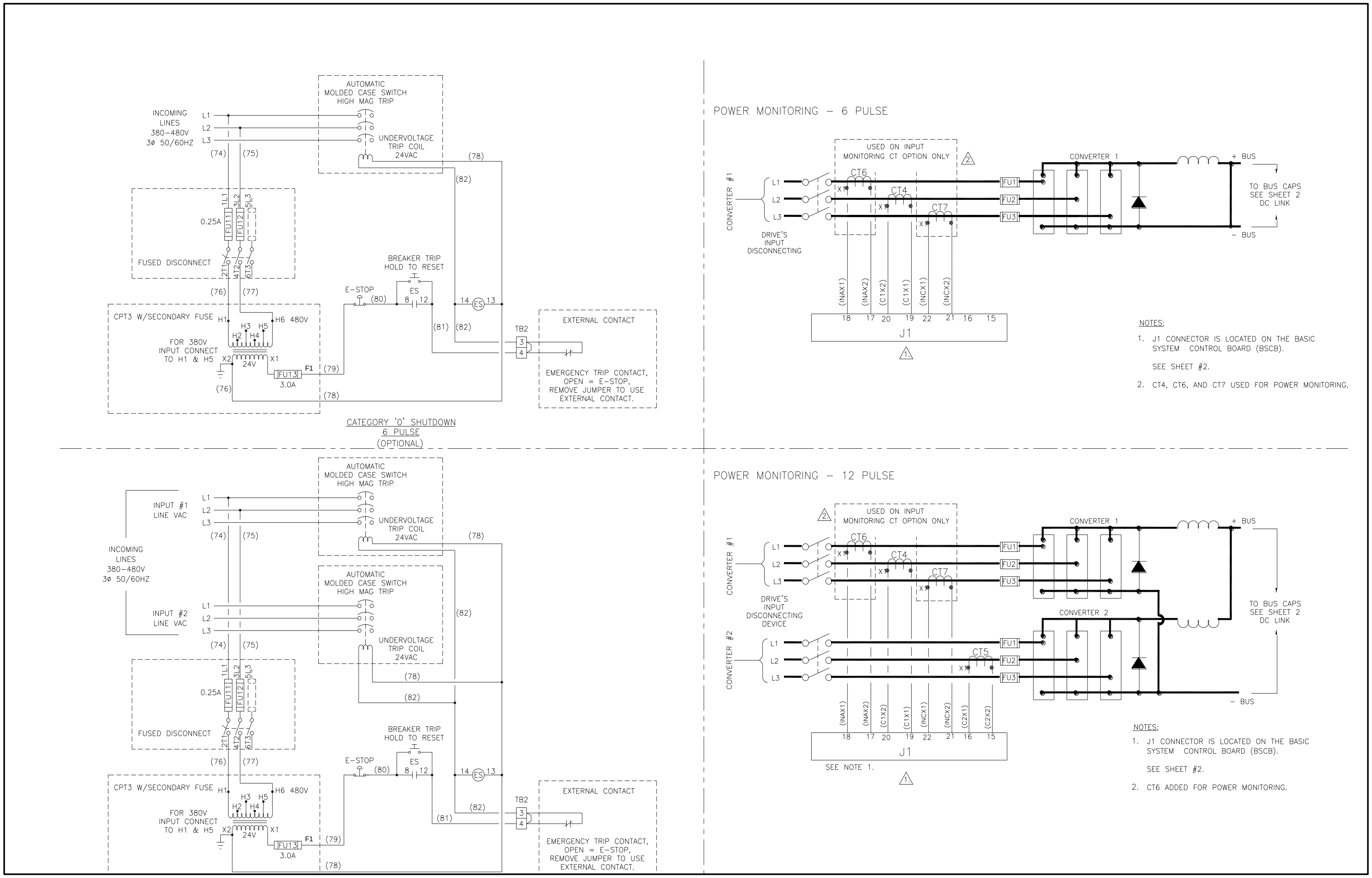


Figure 37: ADVANTAGE 2000/4000 NEMA-1 6&12-PULSE CATEGORY 0 SHUT DOWN & INPUT POWER MONITORING
Drawing reference number-908587, sheet number-4, revision-A, revision date: 12 June 13

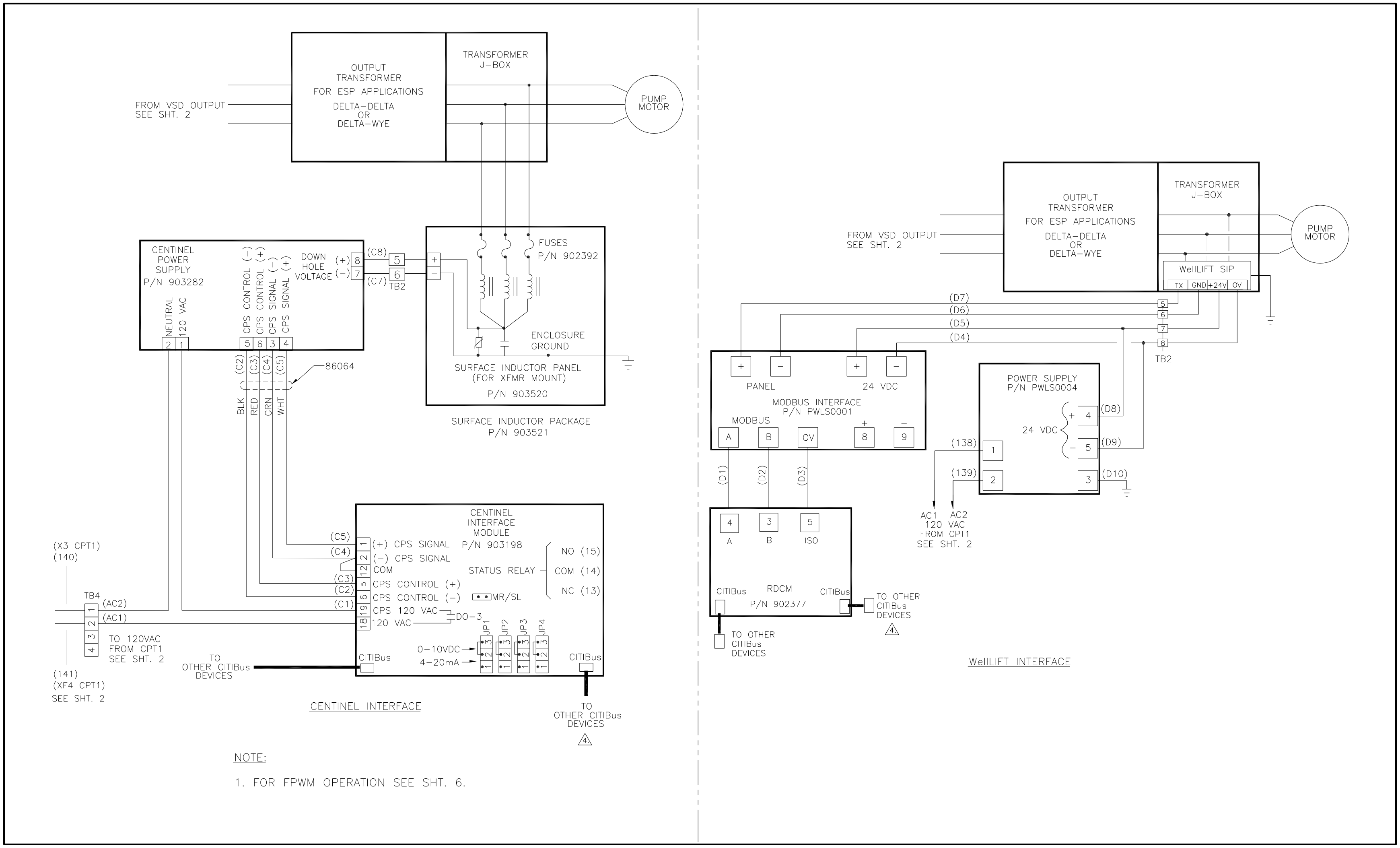


Figure 38: ADVANTAGE 2000/4000 NEMA 1 6-PULSE, 12-PULSE CENTINEL AND WELL LIFT INTERFACE

Drawing reference number-908587, sheet number-4, revision-A, revision date: 12 June 13

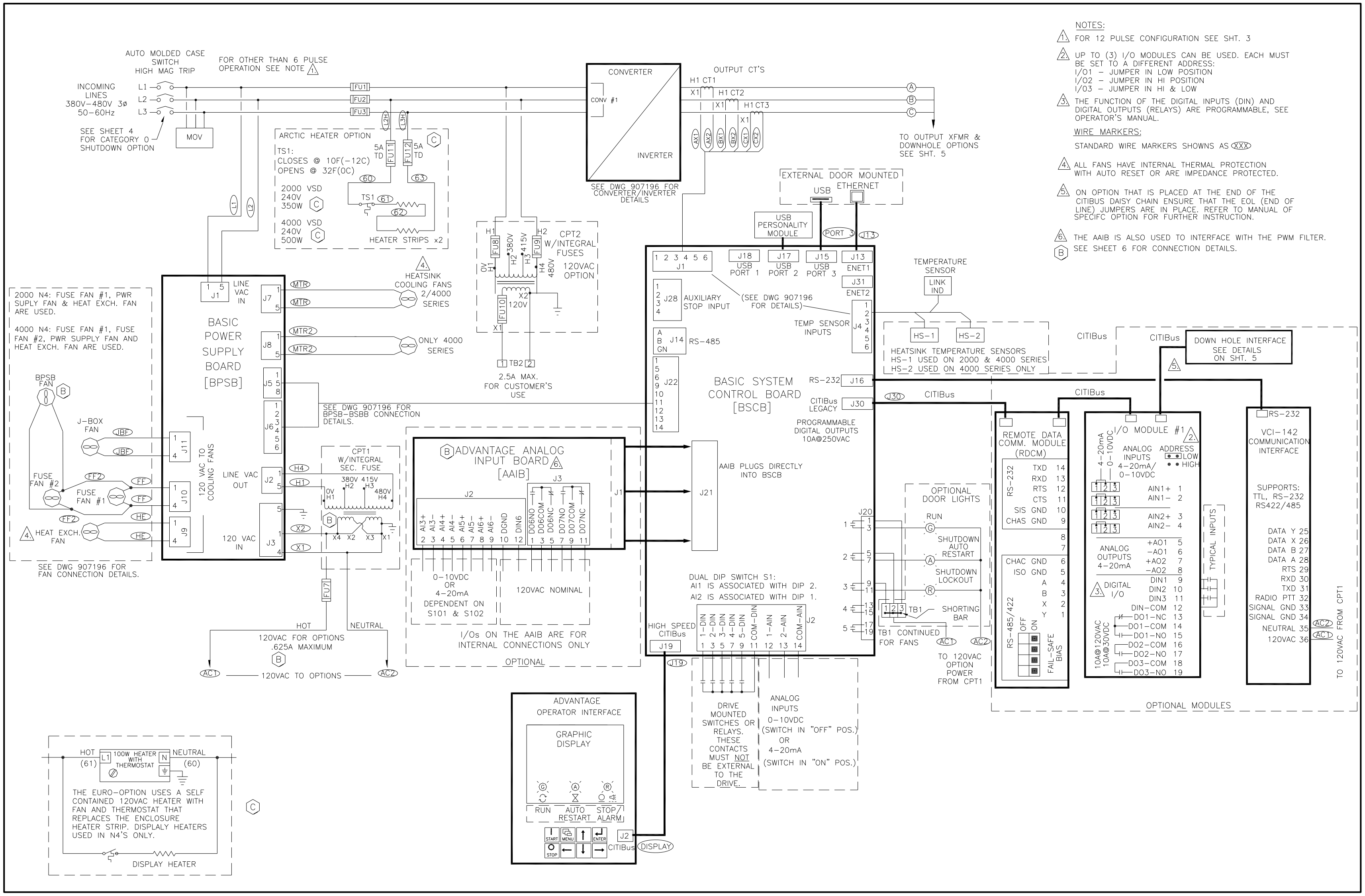


Figure 39: VSD ADVANTAGE SERIES 2000 & 4000 N4 WITH ALL STANDARD OPTIONS

Drawing Number: 907195 - Sheet Number: 2 - Revision: C - Revision Date: 15DEC11

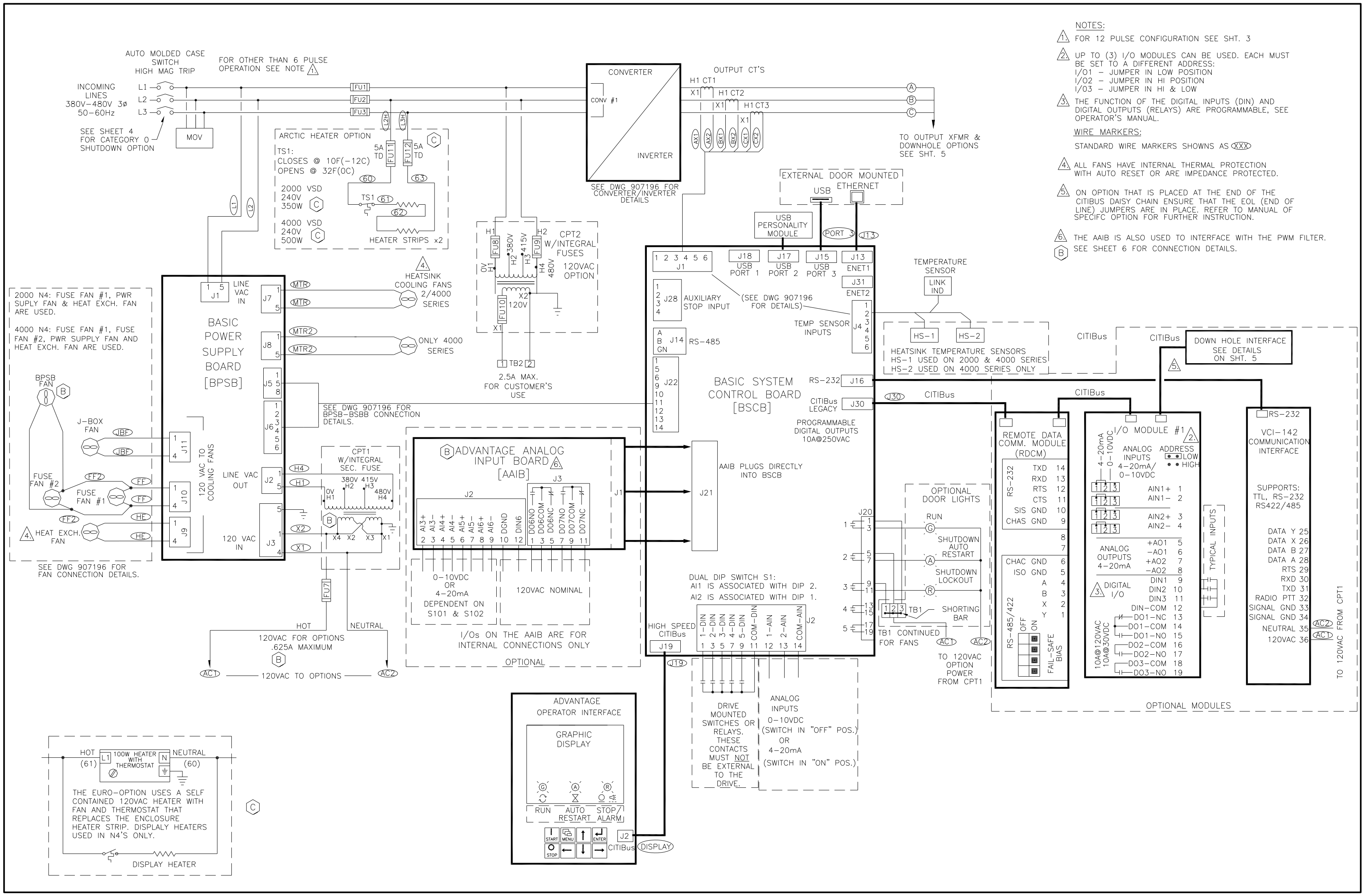
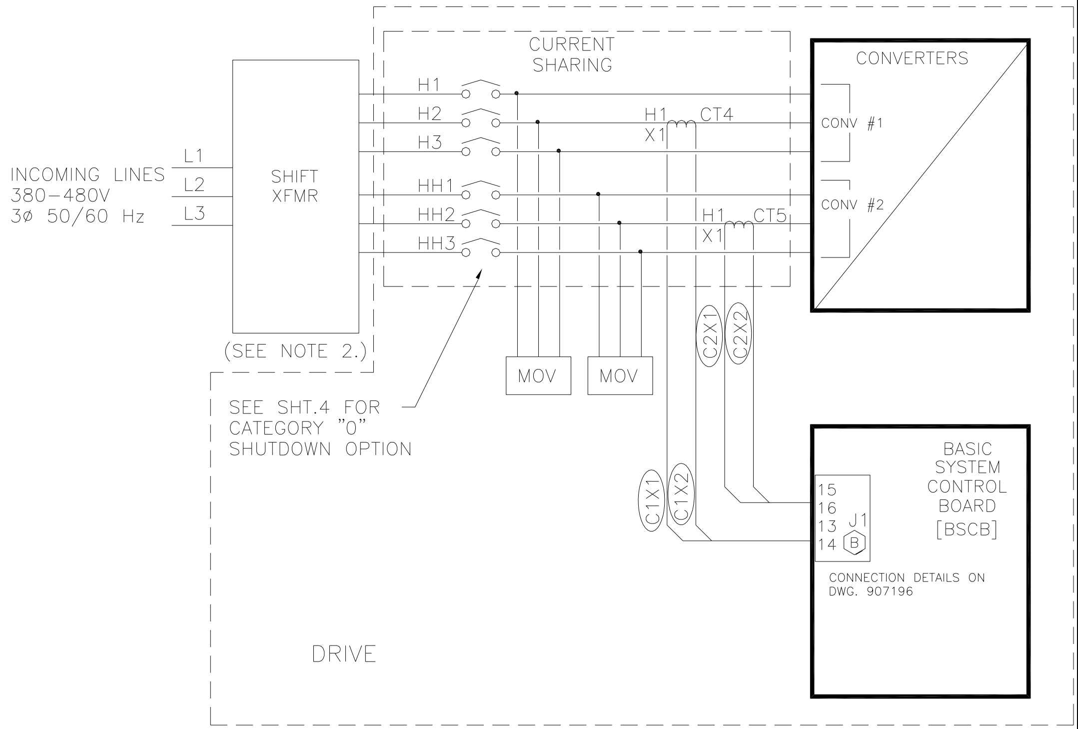


Figure 40: VSD ADVANTAGE SERIES 2000 & 4000 N4 WITH ALL STANDARD OPTIONS

Drawing Number: 907195 - Sheet Number: 2 - Revision: C - Revision Date: 15DEC11



NOTES:

1. FOR 12 PULSE OPERATION EACH SET OF INPUTS MUST BE PHASE SHIFTED 30°.

2. FOR 6 PULSE OPERATION THE SHIFT XFMR IS NOT REQUIRED AND THE INCOMING LINES SHOULD BE CONNECTED TO THE CONVERTER SECTION AS FOLLOWS:
   L1 TO H1 & HH1
   L2 TO H2 & HH2
   L3 TO H3 & HH3

Figure 41: ADVANTAGE SERIES 2000 & 4000 N4 12P CURRENT SHARING
Drawing Number: 907195 -Sheet Number: 3 -Revision: B - Revision Date: 20MAY11

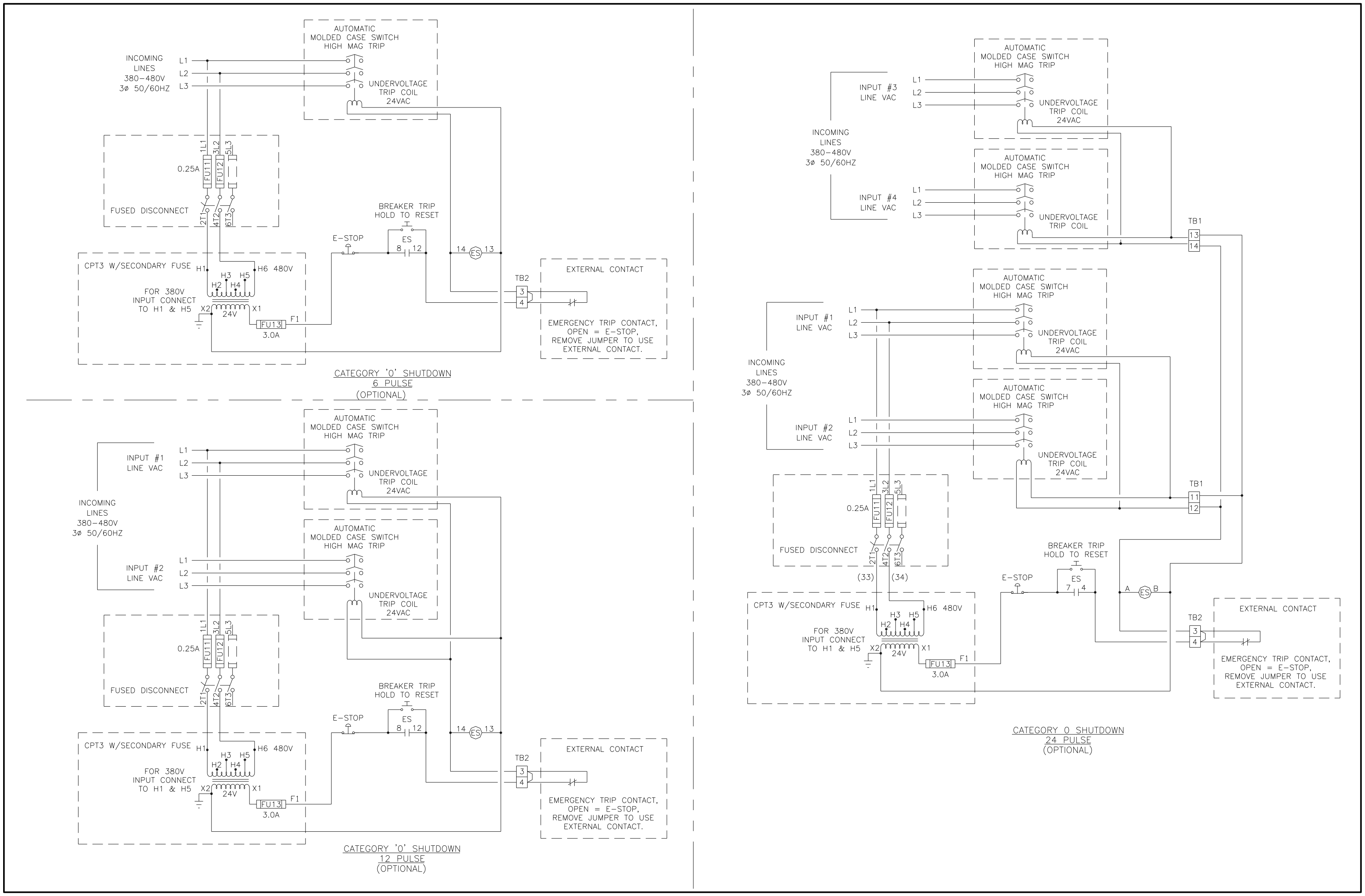


Figure 42: VSD ADVANTAGE SERIES 2000 & 4000 N4 CATEGORY ZERO SHUT DOWN OPTION
Drawing Number: 907195 - Sheet Number: 4 - Revision: C - Revision Date: 15DEC11

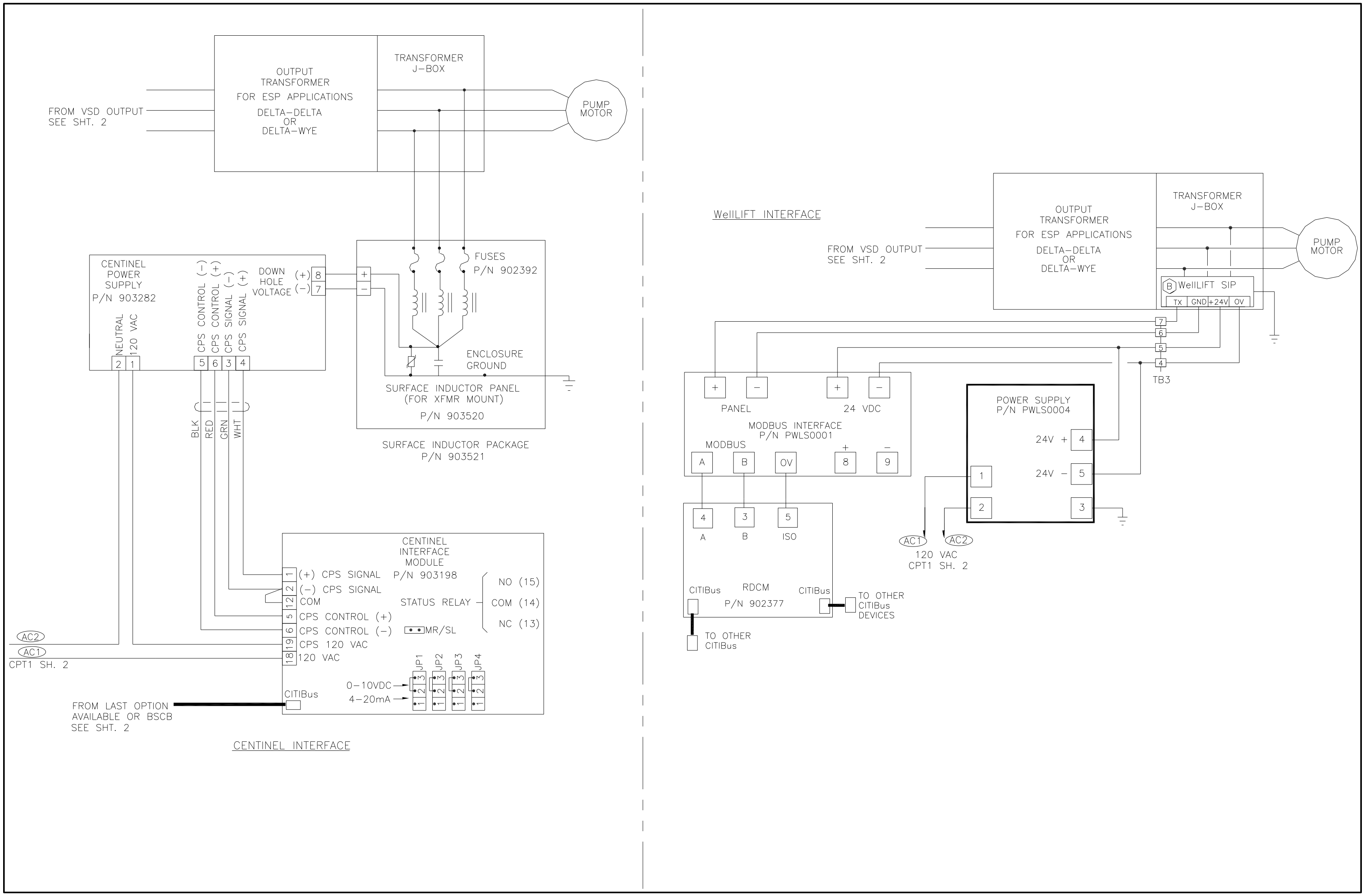


Figure 43: VSD ADVANTAGE SERIES, 2000 & 4000 N4 DOWNHOLE INSTRUMENTATION OPTION
Drawing Number: 907195 - Sheet Number: 5 - Revision: B - Revision Date: 20MAY11

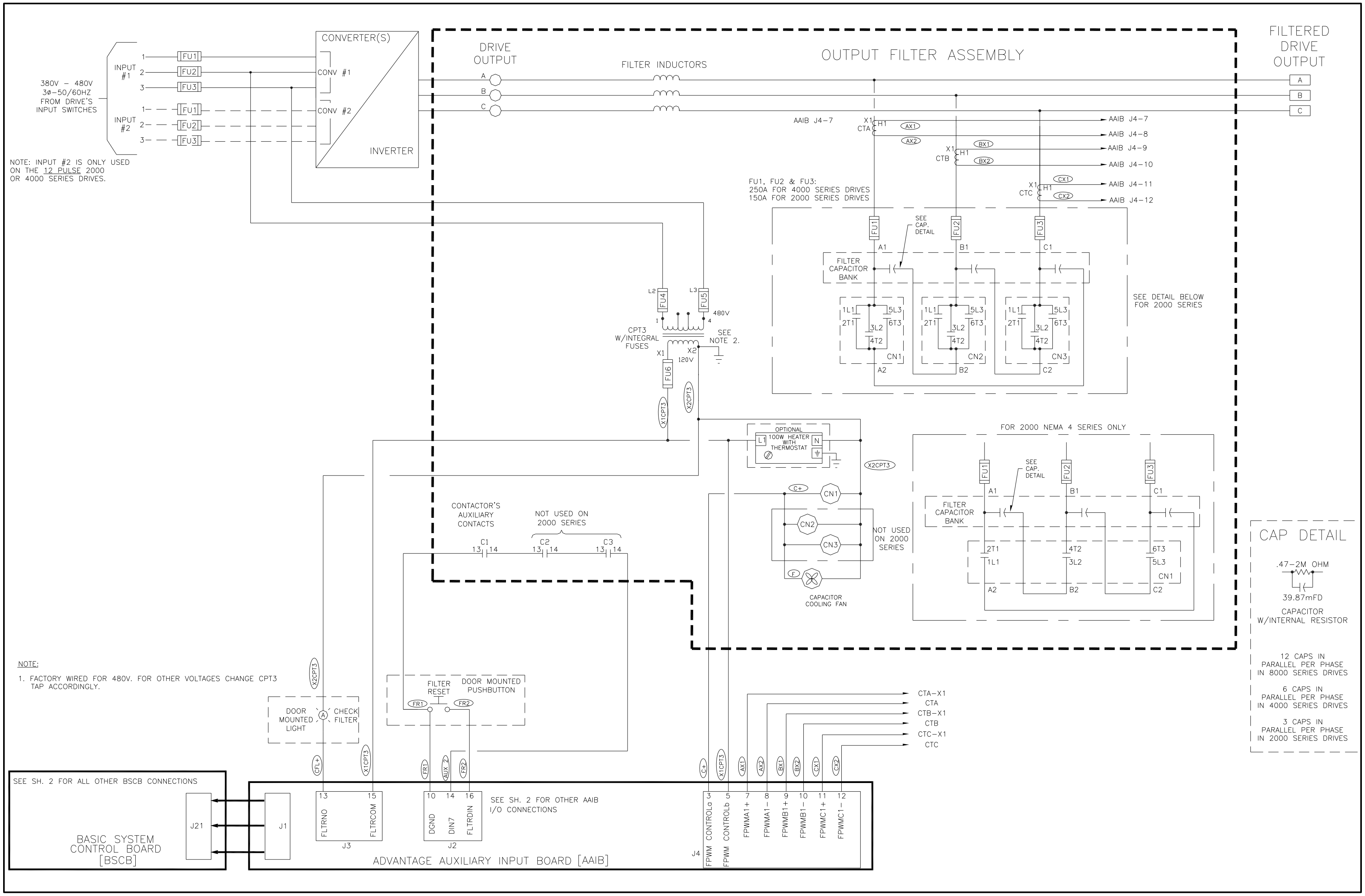


Figure 44: ADVANTAGE SERIES 2000 & 4000 N4 SCH/INTERCONNECT, PWM FILTER TO DRIVE

Drawing Number: 907195 - Sheet Number: 6 - Revision: B - Revision Date: 20MAY11

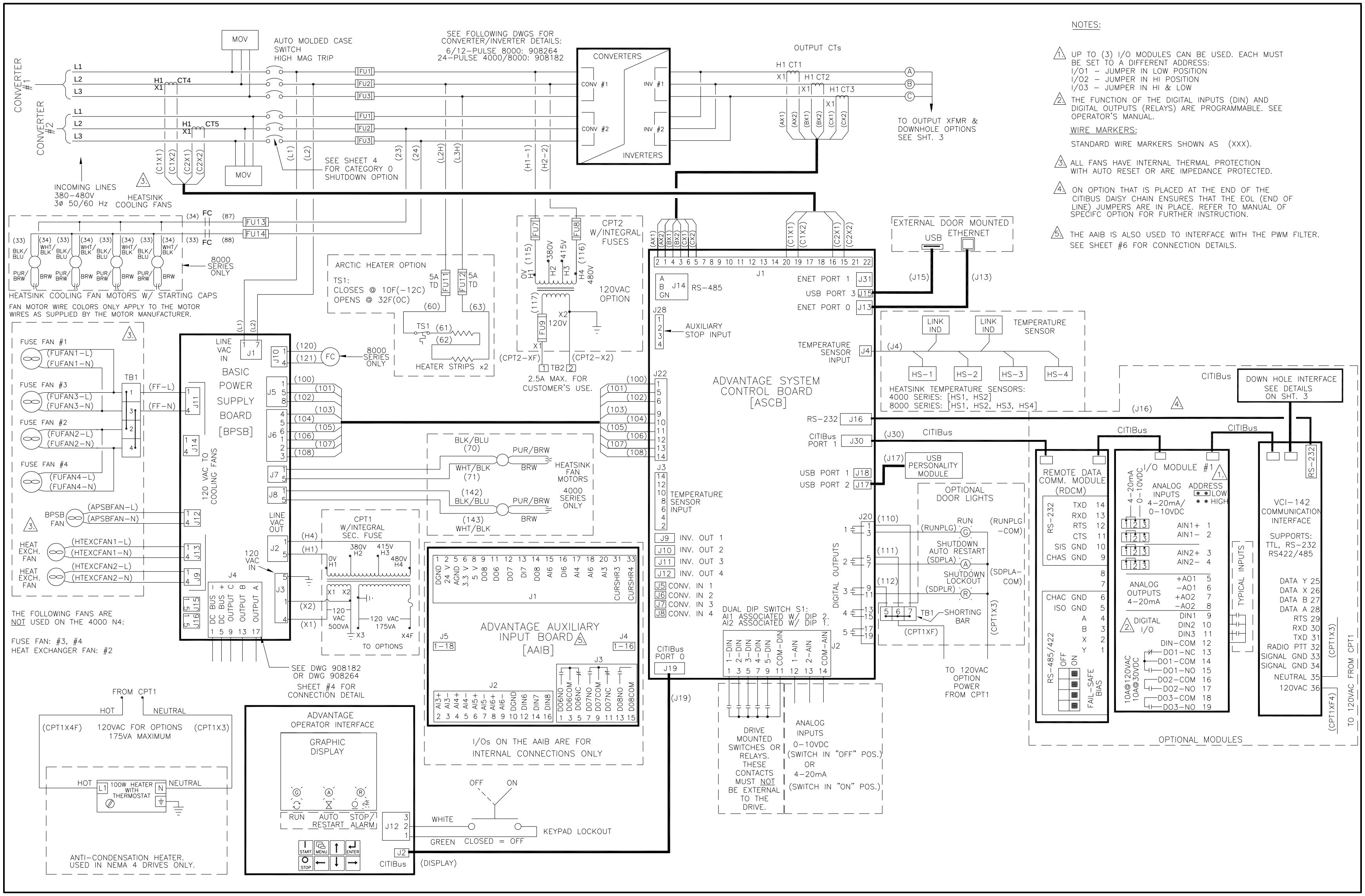


Figure 45: VANTAGE VSD 8N4 6/12 & 24P, 4N4 24P ONLY WITH ALL STANDARD OPTIONS

Drawing Number: 908166 - Sheet Number: 2 - Revision: B - Revision Date: 25MAR13

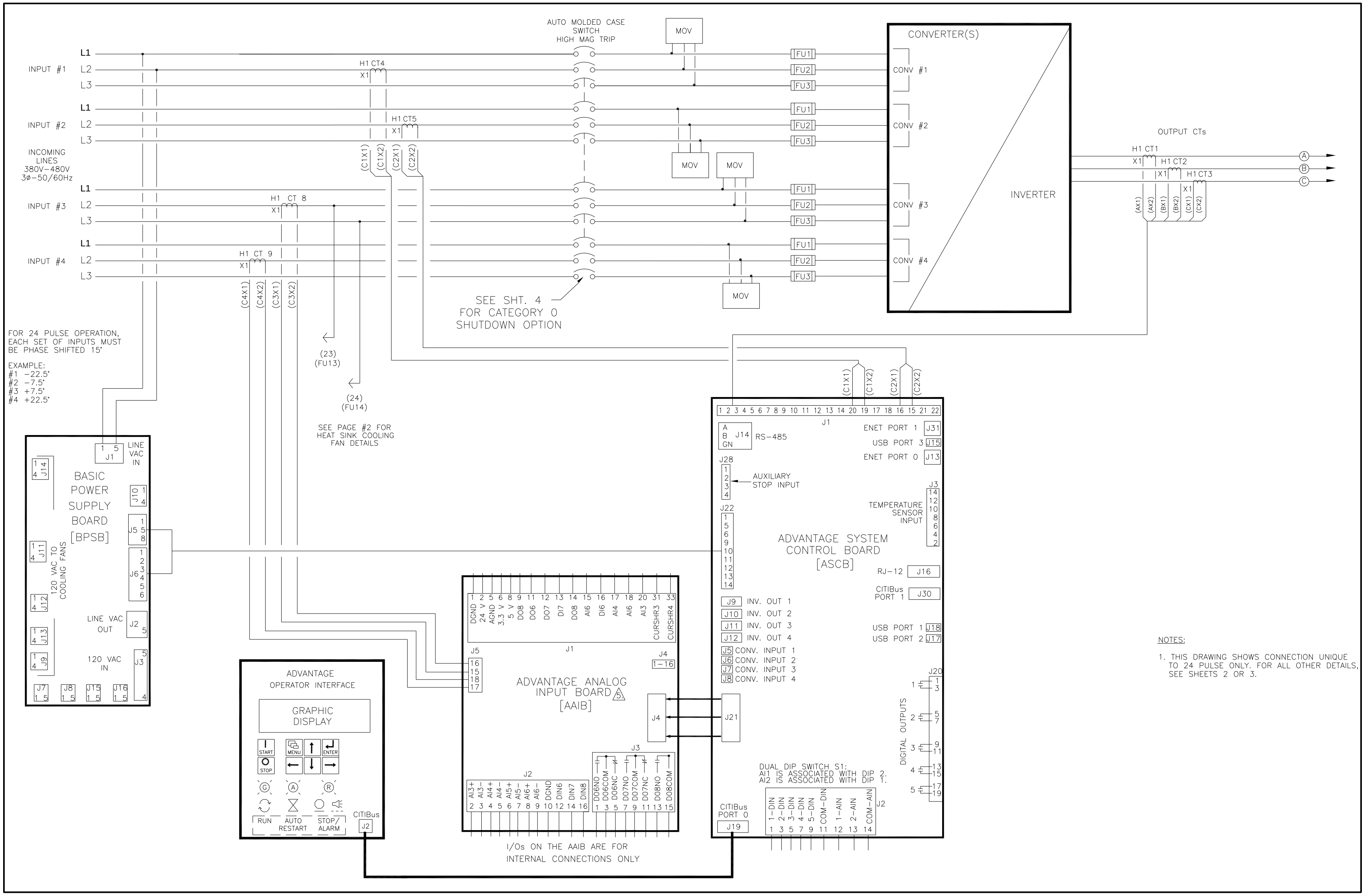


Figure 46: ADVANTAGE 4000-24 PULSE AND SERIES 8000 6/12P, 24 PULSE - CONVERTERS AND CONTROL

Drawing reference number-908166, sheet number-5, revision-A, revision date: 18 Oct 12

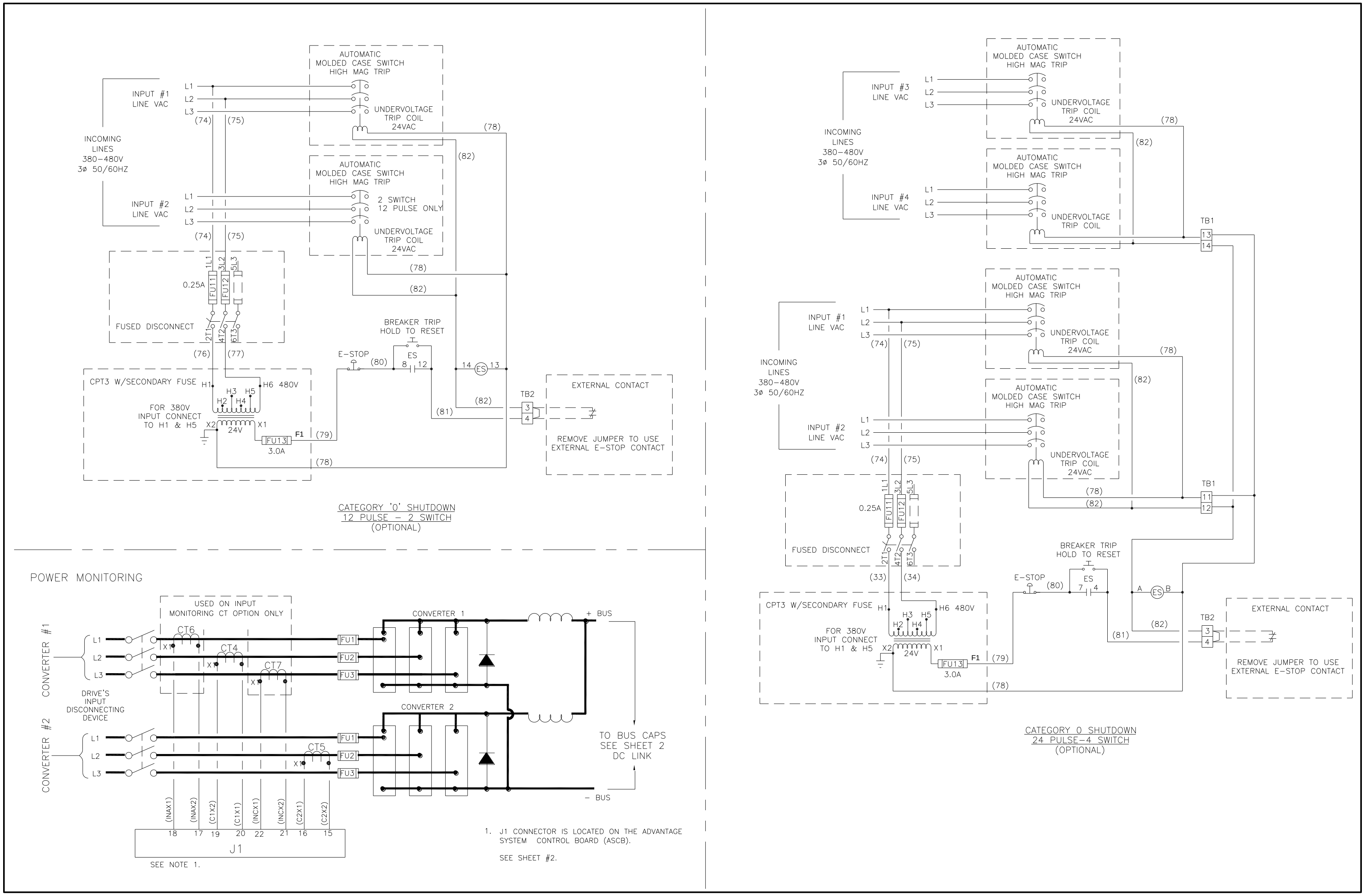


Figure 47: ADVANTAGE 4000-24P & 8000 6/12/24 P CATEGORY '0' SHUTDOWN & POWER MONITORING OPTION
Drawing reference number-908166, sheet number-4, revision-A, revision date: 18 Oct 12

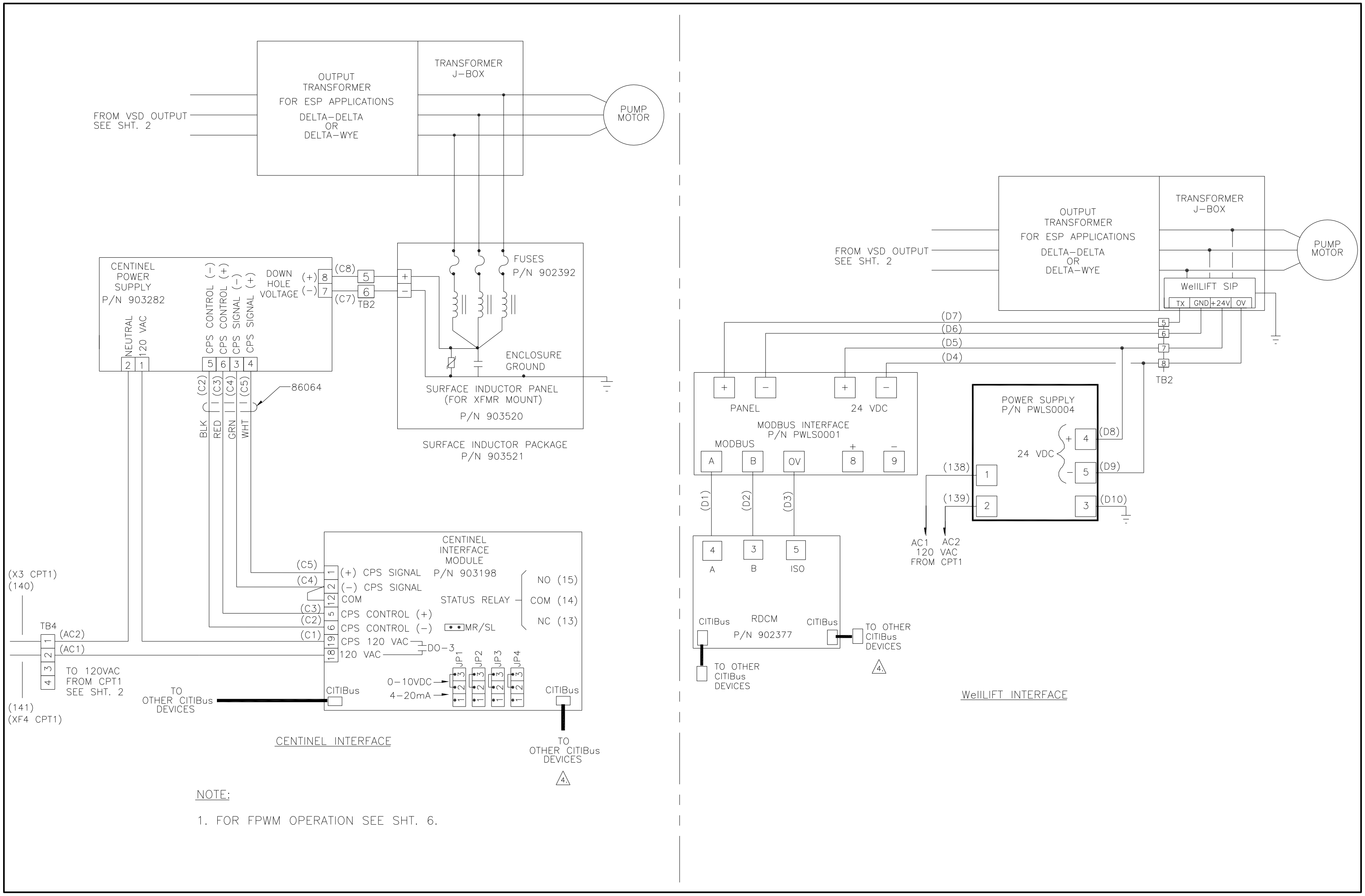


Figure 48: **ADVANTAGE 4000-24P & 8000 6/12P, 24P DOWNHOLE INSTRUMENTATION: CENTINEL AND WELL LIFT INTERFACE**
Drawing reference number-908166, sheet number-3, revision-A, revision date: 18 Oct 12

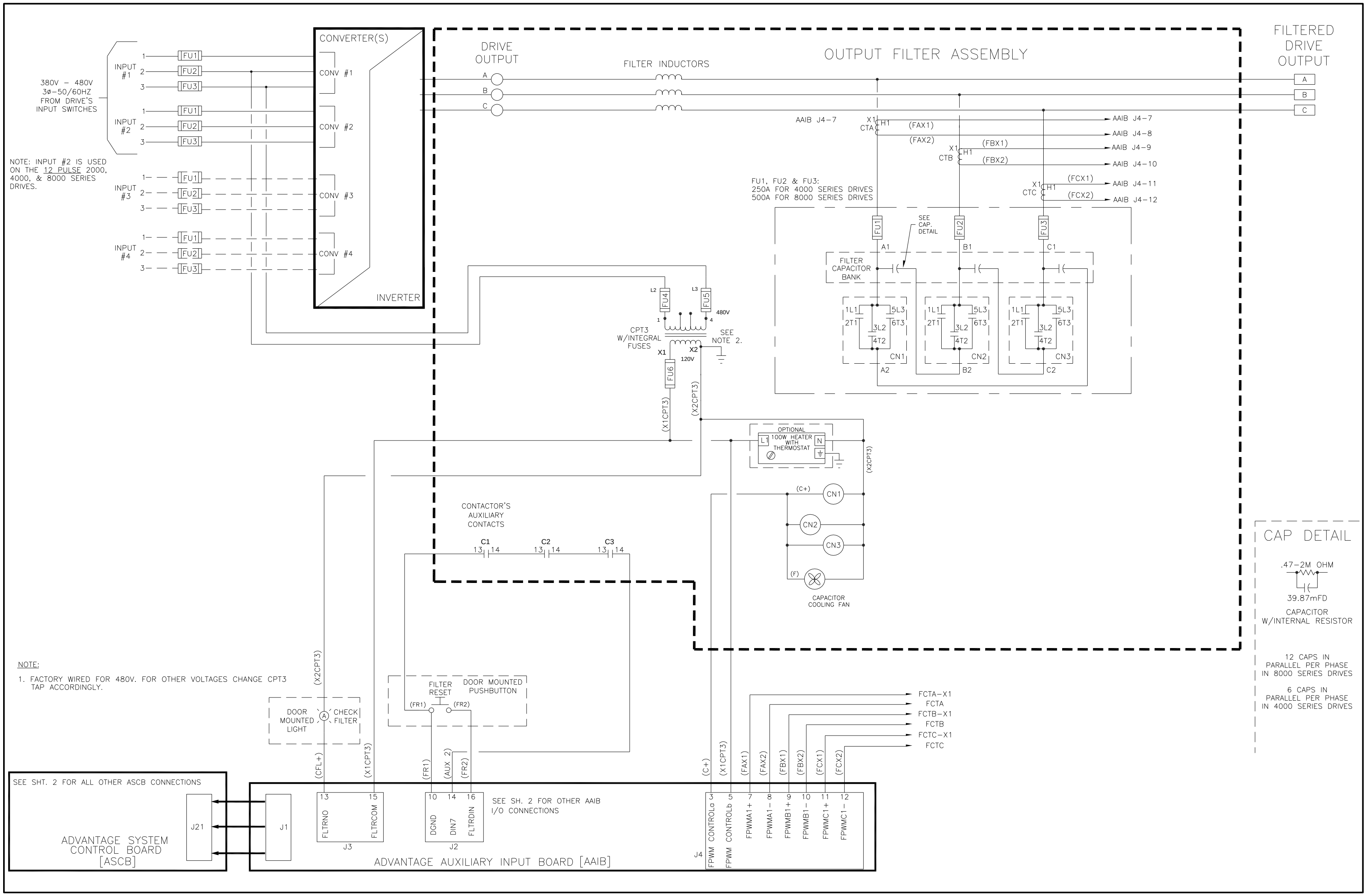


Figure 49: ADVANTAGE 4000-24P AND SERIES 8000 6/12P, 24 P FILTERED PWM OPTION
Drawing reference number-908166, sheet number-6, revision-A, revision date: 18 Oct 12

Power Schematic Diagrams

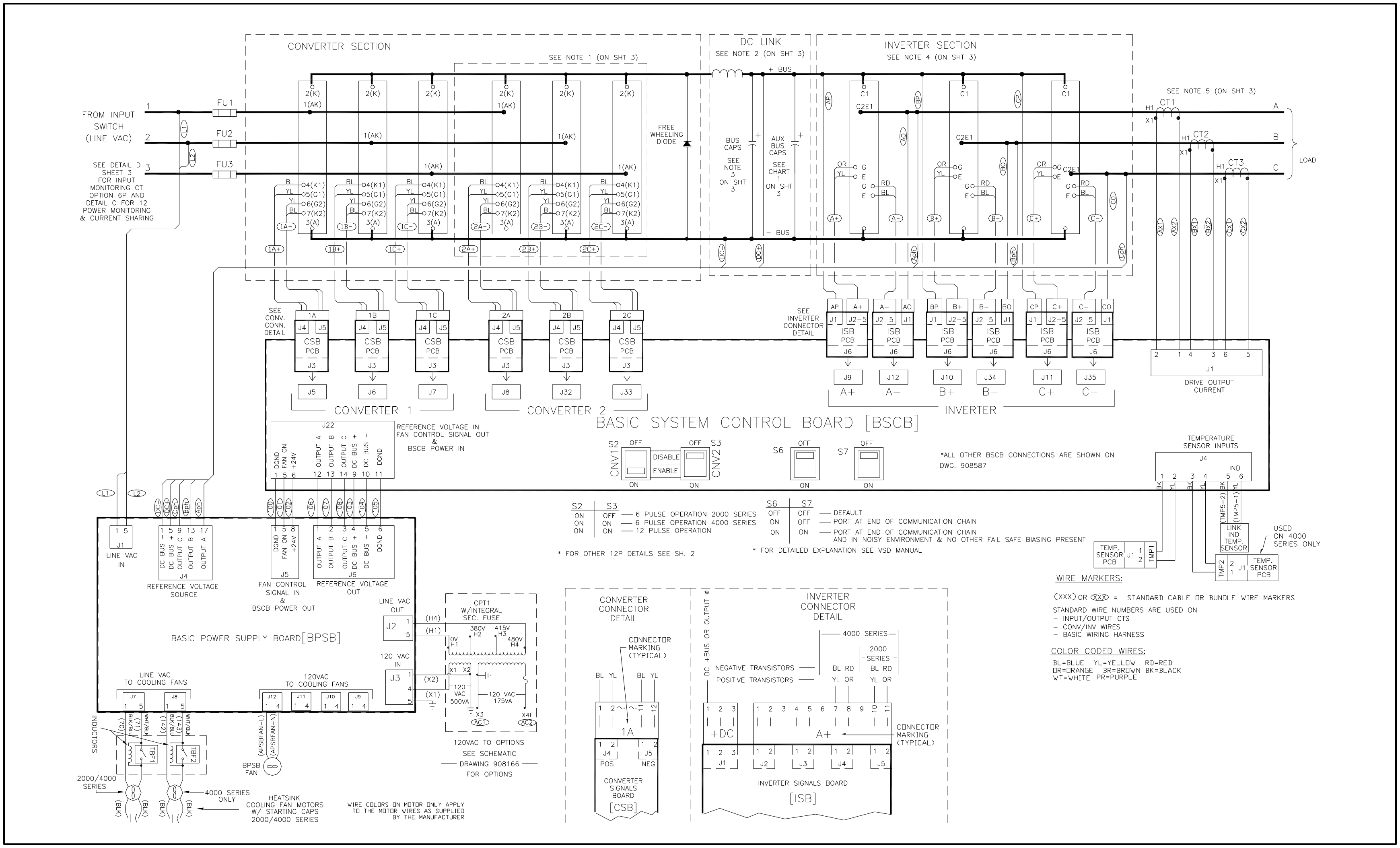
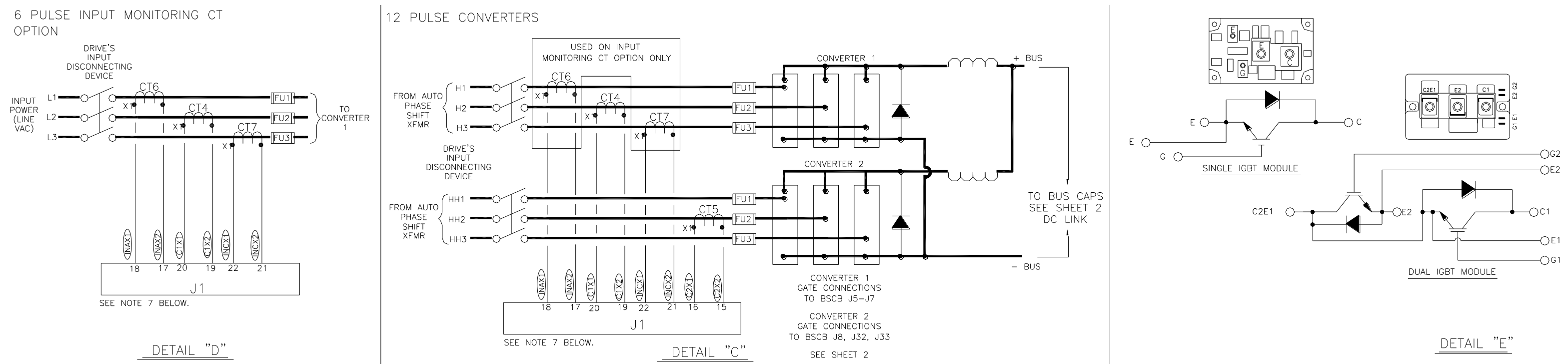


Figure 50: ADVANTAGE 2000/4000 NEMA1 6/12PULSE CONVERTER, CONTROL BOARD, POWER SUPPLY, COOLING FANS, INVERTER

Drawing reference number-908694, sheet number-3, revision-A, revision date: 12 June 13



NOTES:

1. SCR MODULES ARE USED IN PARALLEL IN 12 PULSE APPLICATIONS AND LARGER 6 PULSE VSCS. PARALLEL SCRS ARE SHOWN IN DIAGRAM. SEE DETAIL "C" FOR 12 PULSE CONNECTION. MULTIPLE CONVERTER SIGNALS BOARDS ARE REQUIRED FOR THE ADDITIONAL SET OF THREE MODULES. SEE CHART 1 BELOW. SEE DETAIL "A" FOR SCR MODULE TERMINAL IDENTIFICATION.
2. THE LINK INDUCTOR MAY CONSIST OF MULTIPLE INDUCTORS IN PARALLEL. THE NUMBER IS DETERMINED BY THE VSC RATING. SEE CHART 1 BELOW.
3. THE BUS CAPACITANCE CONSISTS OF PAIRS OF CAPACITORS IN SERIES TO ATTAIN THE REQUIRED VOLTAGE RATINGS. BLEEDER RESISTORS ARE PLACED IN PARALLEL WITH EACH CAPACITOR MODULE CONSISTING OF 4 PAIRS OF CAPACTORS. THE RESISTORS ARE CONTAINED WITHIN THE CAPACTOR MODULE. THE RESISTORS INSURE THE VOLTAGE IS EQUALLY DIVIDED ACROSS THE CAPACTOR MODULE. MULTIPLE CAPACITOR MODULES ARE USED IN PARALLEL TO OBTAIN THE OVERALL CAPACITANCE REQUIRED. THIS CAPACITANCE IS DETERMINED BY THE VSC RATING. SEE CHART 1 BELOW FOR THE NUMBER OF MODULES REQUIRED. SEE SCHEMATIC DETAIL "B".
4. IGBT MODULES ARE USED IN SERIES AND PARALLEL TO ACHIEVE THE REQUIRED RATINGS. THIS SCHEMATIC SHOWS ONE MODULE PER PHASE. ADDITIONAL MODULES ARE CONNECTED AS SHOWN IN SCHEMATIC DETAIL "D". SEE DETAIL "E" FOR IGBT MODULE TERMINAL IDENTIFICATION. SEE CHART 1 BELOW.
5. CT1, CT2, AND CT3 HAVE DIFFERENT CURRENT RATIOS DEPENDING ON VSC RATING. SEE CHART 1 BELOW FOR CT RATIO FOR EACH VSC RATING.
6. MULTIPLE DIODE MODULES ARE USED TO ACHIEVE THE REQUIRED RATINGS. SEE CHART 1 BELOW. THE QUANTITY OF SCRS, INDUCTORS, CAPACITOR MODULES, TEMP SENSORS, AND IGBTS VARY DEPENDING ON THE VSC RATING. THE VSC MODEL DETERMINES THE NUMBER OF OTHER COMPONENTS. SEE CHART 1 BELOW.
7. J1 CONNECTOR IS LOCATED ON THE BASIC SYSTEM CONTROL BOARD (BSCB). SEE SHEET 2.

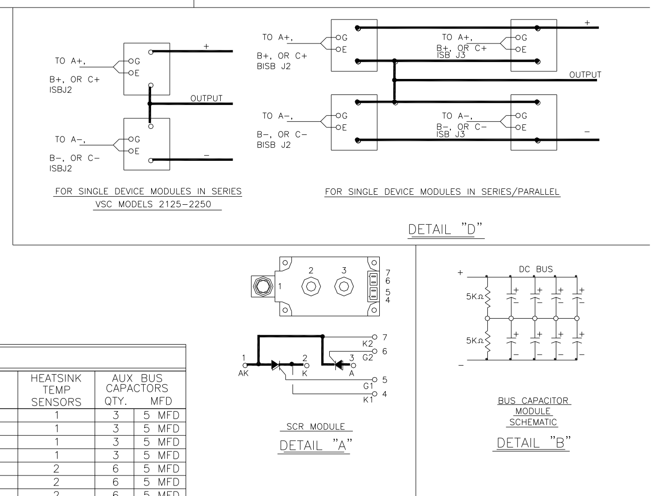


CHART 1

MODEL -6= 6 PULSE -12= 12 PUL.	IGBT TYPE	IGBT PER PHASE	SCR MODULES PER PHASE	CONVERTER BOARD TYPE	CONVERTER BOARD QTY.	DIODE MODULES	INDUCTORS 200A	INDUCTORS 100A	INDUCTORS 50A	CAPACTOR MODULES	CT RATIO	FUSES	FANS	HEATSINK TEMP SENSORS	AUX BUS CAPACITORS QTY.	AUX BUS CAPACITORS MFD
2060-6	200A	2	1	CSB	3	1	0	1	0	1	250:1	100A	1	1	3	5 MFD
2125-6	400A	2	1	CSB	3	1	1	0	0	2	250:1	200A	1	1	3	5 MFD
2200-6	400A	2	1	CSB	3	2	1	1	0	3	500:1	300A	1	1	3	5 MFD
2250-6	600A	2	1	CSB	3	2	2	0	0	4	500:1	400A	1	1	3	5 MFD
4300-6	400A	4	2	CSB	6	1	2	1	0	5	500:1	500A	2	2	6	5 MFD
4350-6	400A	4	2	CSB	6	2	3	0	0	6	500:1	600A	2	2	6	5 MFD
4400-6	600A	4	2	CSB	6	2	3	1	0	7	1000:1	700A	2	2	6	5 MFD
4500-6	600A	4	2	CSB	6	2	4	0	0	8	1000:1	800A	2	2	6	5 MFD
2060-12	200A	2	2	CSB	6	2	0	0	2	1	250:1	2-50A	1	1	3	5 MFD
2125-12	400A	2	2	CSB	6	2	0	2	0	2	250:1	2-100A	1	1	3	5 MFD
2200-12	400A	2	2	CSB	6	2	2	0	0	4	500:1	2-150A	1	1	3	5 MFD
2250-12	600A	2	2	CSB	6	2	2	0	0	4	500:1	2-200A	1	1	3	5 MFD
4300-12	400A	4	2	CSB	6	2	2	0	2	5	500:1	2-250A	2	2	6	5 MFD
4350-12	400A	4	2	CSB	6	2	2	2	0	6	500:1	2-300A	2	2	6	5 MFD
4400-12	600A	4	2	CSB	6	2	4	0	0	8	1000:1	2-350A	2	2	6	5 MFD
4500-12	600A	4	2	CSB	6	2	4	0	0	8	1000:1	2-400A	2	2	6	5 MFD

Figure 51: ADVANTAGE 2000/4000 NEMA 1 DETAIL: 12-PULSE CONVERTER, 6/12 INPUT MONITORING, IGBT, SCR DIODE DC BUS

Drawing reference number-908694, sheet number-2, revision-A, revision date: 12 June 13

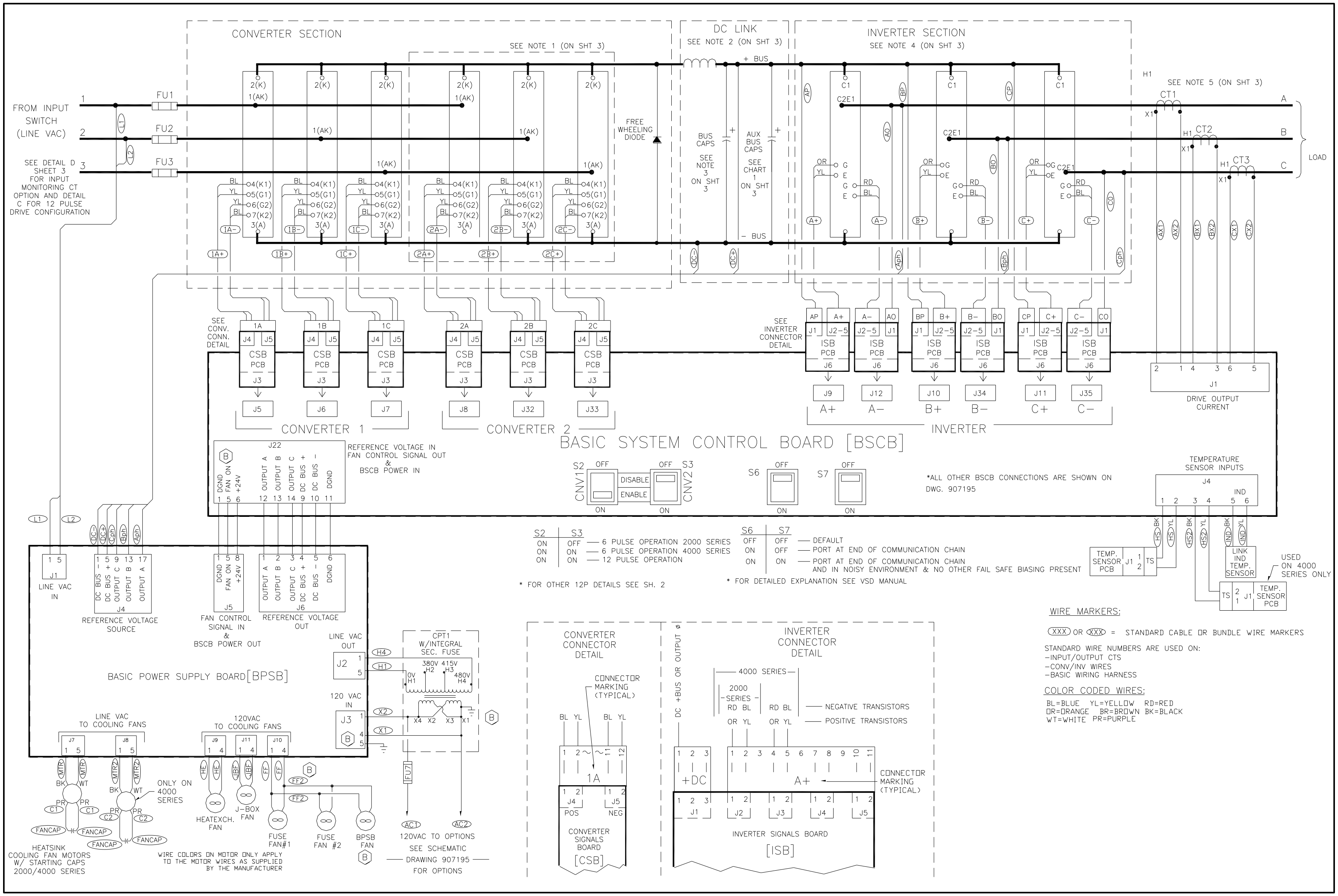
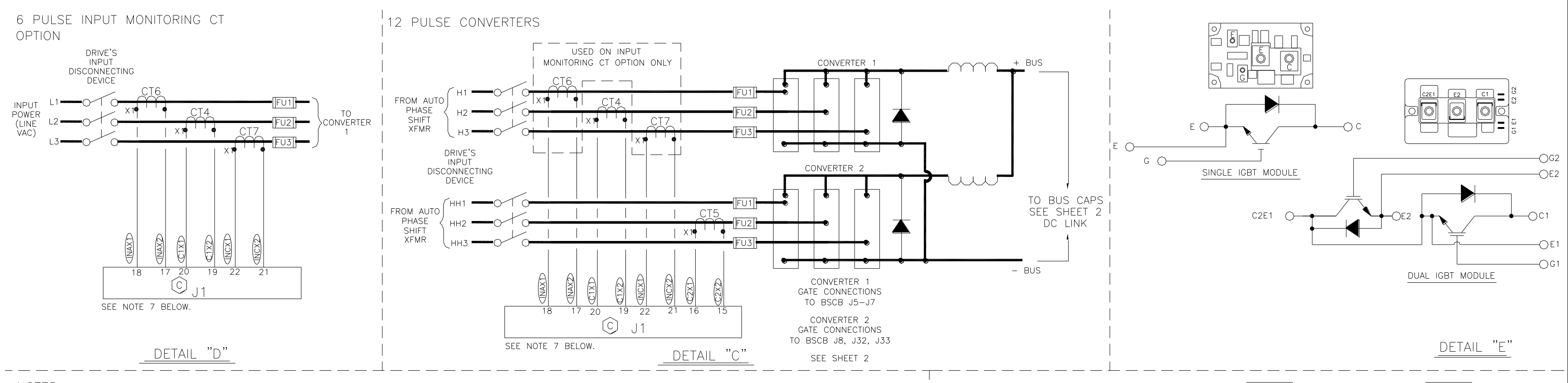


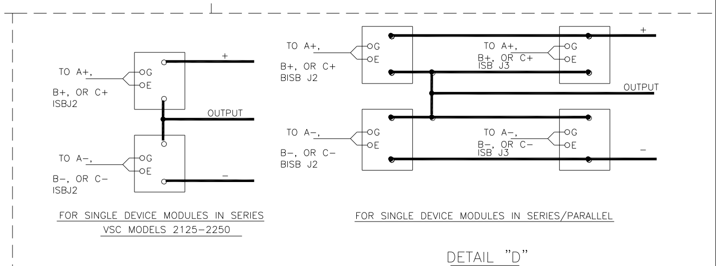
Figure 52: ADVANTAGE 2000/4000 NEMA 4 - 6/12PULSE CONVERTER, CONTROL BOARD, POWER SUPPLY, COOLING FANS, INVERTER

Drawing reference number-907196, sheet number-2, revision-B, revision date: 12 Mar 12



NOTES:

1. SCR MODULES ARE USED IN PARALLEL IN 12 PULSE APPLICATIONS AND LARGER 6 PULSE VSCS. PARALLEL SCRS ARE SHOWN IN DIAGRAM. SEE DETAIL "C" FOR 12 PULSE CONNECTION. MULTIPLE CONVERTER SIGNALS BOARDS ARE REQUIRED FOR THE ADDITIONAL SET OF THREE MODULES. SEE CHART 1 BELOW. SEE DETAIL "A" FOR SCR MODULE TERMINAL IDENTIFICATION.
2. THE LINK INDUCTOR MAY CONSIST OF MULTIPLE INDUCTORS IN PARALLEL. THE NUMBER IS DETERMINED BY THE VSC RATING. SEE CHART 1 BELOW.
3. THE BUS CAPACITANCE CONSISTS OF PAIRS OF CAPACITORS IN SERIES TO ATTAIN THE REQUIRED VOLTAGE RATINGS. BLEEDER RESISTORS ARE PLACED IN PARALLEL WITH EACH CAPACITOR MODULE CONSISTING OF 4 PAIRS OF CAPACTORS. THE RESISTORS ARE CONTAINED WITHIN THE CAPACITOR MODULE. THE RESISTORS INSURE THE VOLTAGE IS EQUALLY DIVIDED ACROSS THE CAPACTOR MODULE. MULTIPLE CAPACITOR MODULES ARE USED IN PARALLEL TO OBTAIN THE OVERALL CAPACITANCE REQUIRED. THIS CAPACITANCE IS DETERMINED BY THE VSC RATING. SEE CHART 1 BELOW FOR THE NUMBER OF MODULES REQUIRED. SEE SCHEMATIC DETAIL "B".
4. IGBT MODULES ARE USED IN SERIES AND PARALLEL TO ACHIEVE THE REQUIRED RATINGS. THIS SCHEMATIC SHOWS ONE MODULE PER PHASE. ADDITIONAL MODULES ARE CONNECTED AS SHOWN IN SCHEMATIC DETAIL "D". SEE DETAIL "E" FOR IGBT MODULE TERMINAL IDENTIFICATION. SEE CHART 1 BELOW.
5. CT1, CT2, AND CT3 HAVE DIFFERENT CURRENT RATIOS DEPENDING ON VSC RATING. SEE CHART 1 BELOW FOR CT RATIO FOR EACH VSC RATING.
6. MULTIPLE DIODE MODULES ARE USED TO ACHIEVE THE REQUIRED RATINGS. SEE CHART 1 BELOW. THE QUANTITY OF SCRS, INDUCTORS, CAPACITOR MODULES, TEMP SENSORS, AND IGBTS VARY DEPENDING ON THE VSC RATING. THE VSC MODEL DETERMINES THE NUMBER OF OTHER COMPONENTS. SEE CHART 1 BELOW.
7. J1 CONNECTOR IS LOCATED ON THE BASIC SYSTEM CONTROL BOARD (BSCB). SEE SHEET 2.



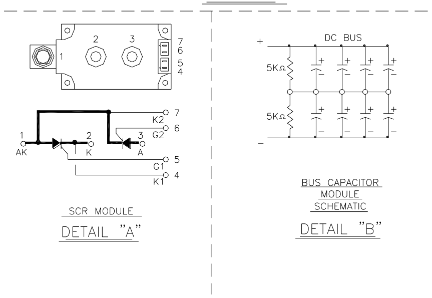


CHART 1

MODEL -6= 6 PULSE -12= 12 PUL.	IGBT TYPE	IGBT PER PHASE	SCR MODULES PER PHASE	CONVERTER BOARD TYPE	CONVERTER BOARD QTY.	DIODE MODULES	INDUCTORS 200A	INDUCTORS 100A	INDUCTORS 50A	CAPACITOR MODULES	CT RATIO	FUSES	FANS	HEATSINK TEMP SENSORS	AUX BUS CAPACITORS QTY.	AUX BUS CAPACITORS MFD
2060-6	200A	2	1	CSB	3	1	0	1	0	1	250:1	100A	1	1	3	5 MFD
2125-6	400A	2	1	CSB	3	1	1	0	0	2	250:1	200A	1	1	3	5 MFD
2200-6	400A	2	1	CSB	3	2	1	1	0	3	500:1	300A	1	1	3	5 MFD
2250-6	600A	2	1	CSB	3	2	2	0	0	4	500:1	400A	1	1	3	5 MFD
4300-6	400A	4	2	CSB	6	1	2	1	0	5	500:1	500A	2	2	6	5 MFD
4350-6	400A	4	2	CSB	6	2	3	0	0	6	500:1	600A	2	2	6	5 MFD
4400-6	600A	4	2	CSB	6	2	3	1	0	7	1000:1	700A	2	2	6	5 MFD
4500-6	600A	4	2	CSB	6	2	4	0	0	8	1000:1	800A	2	2	6	5 MFD
2060-12	200A	2	2	CSB	6	2	0	0	2	1	250:1	2-50A	1	1	3	5 MFD
2125-12	400A	2	2	CSB	6	2	0	2	0	2	250:1	2-100A	1	1	3	5 MFD
2200-12	400A	2	2	CSB	6	2	2	0	0	4	500:1 (B)	2-150A	1	1	3	5 MFD
2250-12	600A	2	2	CSB	6	2	2	0	0	4	500:1	2-200A	1	1	3	5 MFD
4300-12	400A	4	2	CSB	6	2	2	0	2	5	500:1	2-250A	2	2	6	5 MFD
4350-12	400A	4	2	CSB	6	2	2	2	0	6	500:1	2-300A	2	2	6	5 MFD
4400-12	600A	4	2	CSB	6	2	4	0	0	8	1000:1 (B)	2-350A	2	2	6	5 MFD
4500-12	600A	4	2	CSB	6	2	4	0	0	8	1000:1	2-400A	2	2	6	5 MFD

Figure 53: : ADVANTAGE 2000/4000 NEMA4 DETAIL: 12 PULSE CONVERTER, 6 PULSE INPUT MONITORING, IGBT, SCR, DIODE, DC BUS

Drawing Number: 907196 - Sheet Number: 3 - Revision: C - Revision Date:12MAR12

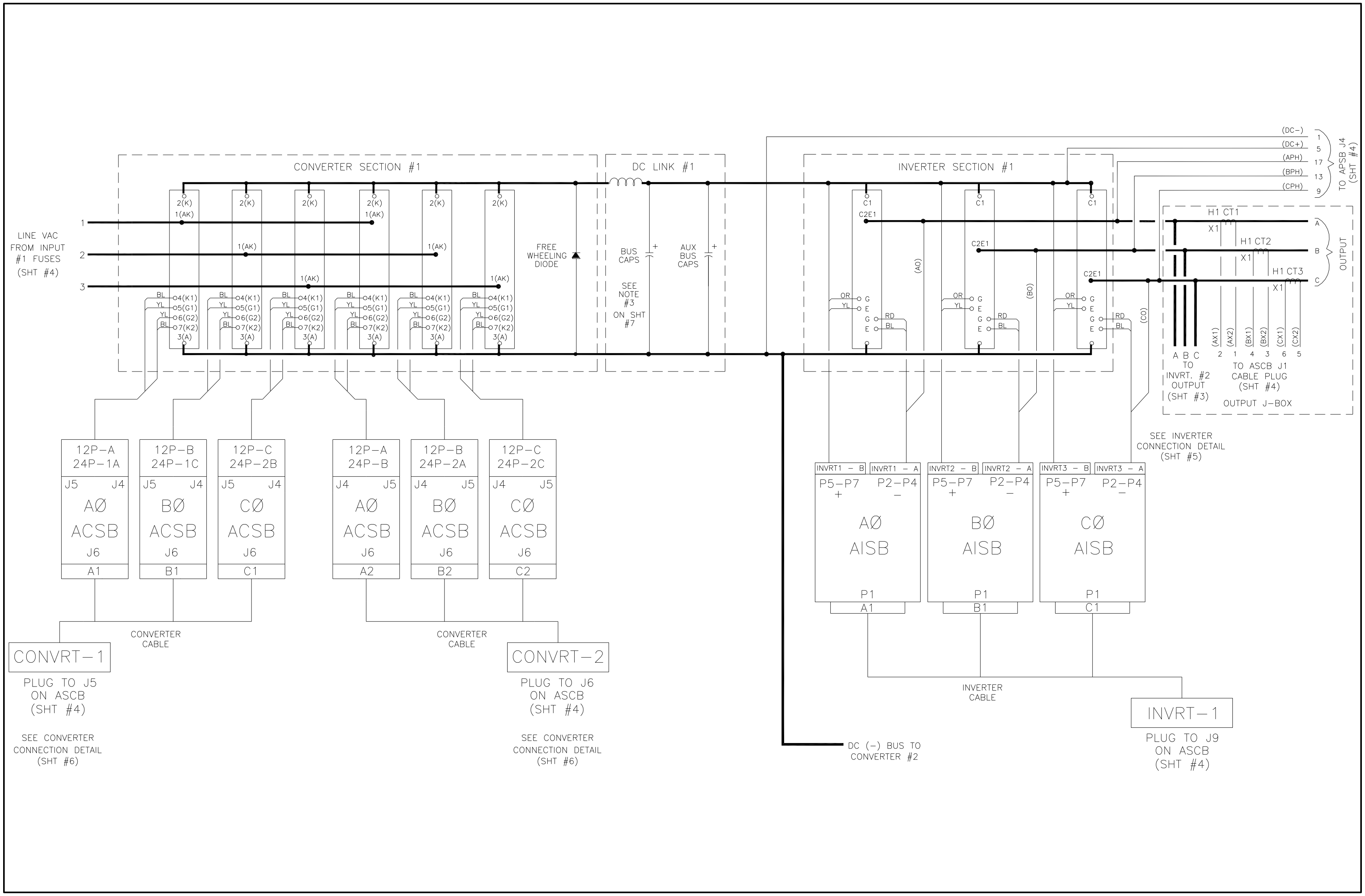


Figure 54: ADVANTAGE 8000 NEMA4 6/12 PULSE DETAIL: CONVERTER 1 AND INVERTER 1

Drawing Number:908264 - Sheet Number:2 - Revision:A - Revision Date:18OCT12

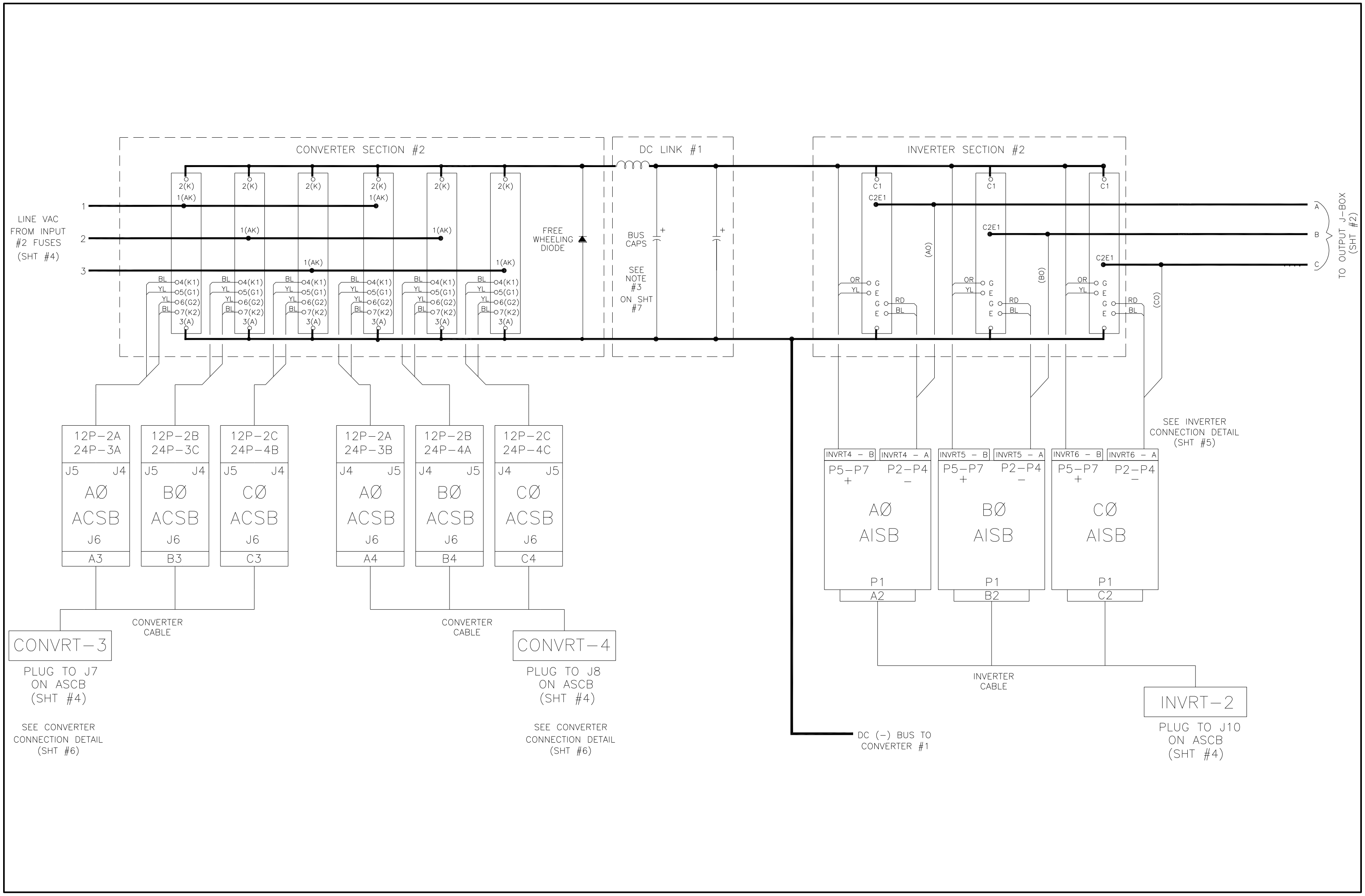


Figure 55: ADVANTAGE 8000 NEMA4 6/12 PULSE DETAIL: CONVERTER 2 AND INVERTER 2
Drawing Number:908264 - Sheet Number:3 - Revision: A - Revision Date:18OCT12

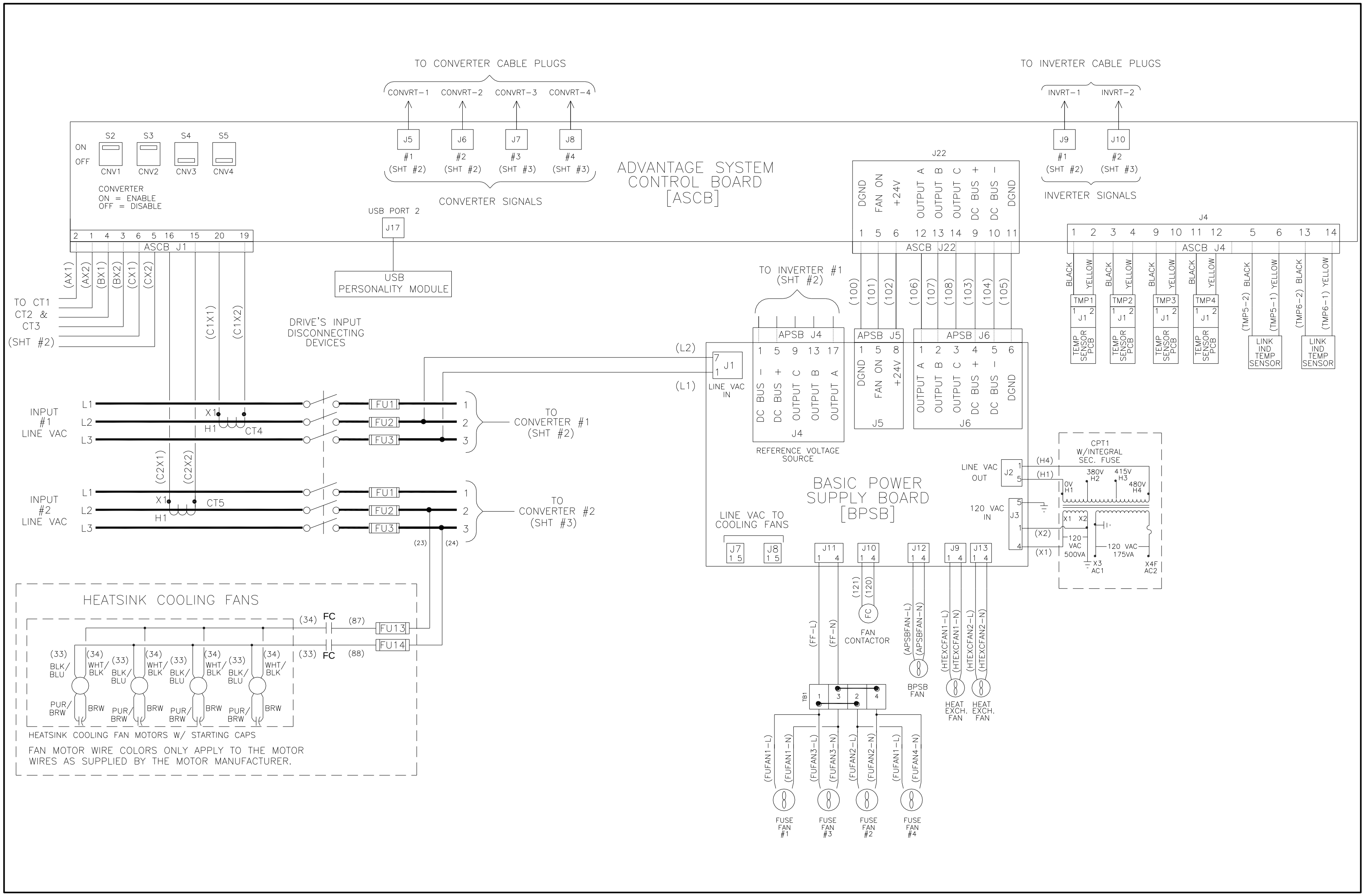


Figure 56: ADVANTAGE 8000 NEMA4 6/12 PULSE DETAIL: CONTROL BOARD, POWER SUPPLY, COOLING FANS

Drawing Number:908264 - Sheet Number:3 - Revision: A - Revision Date:18OCT12

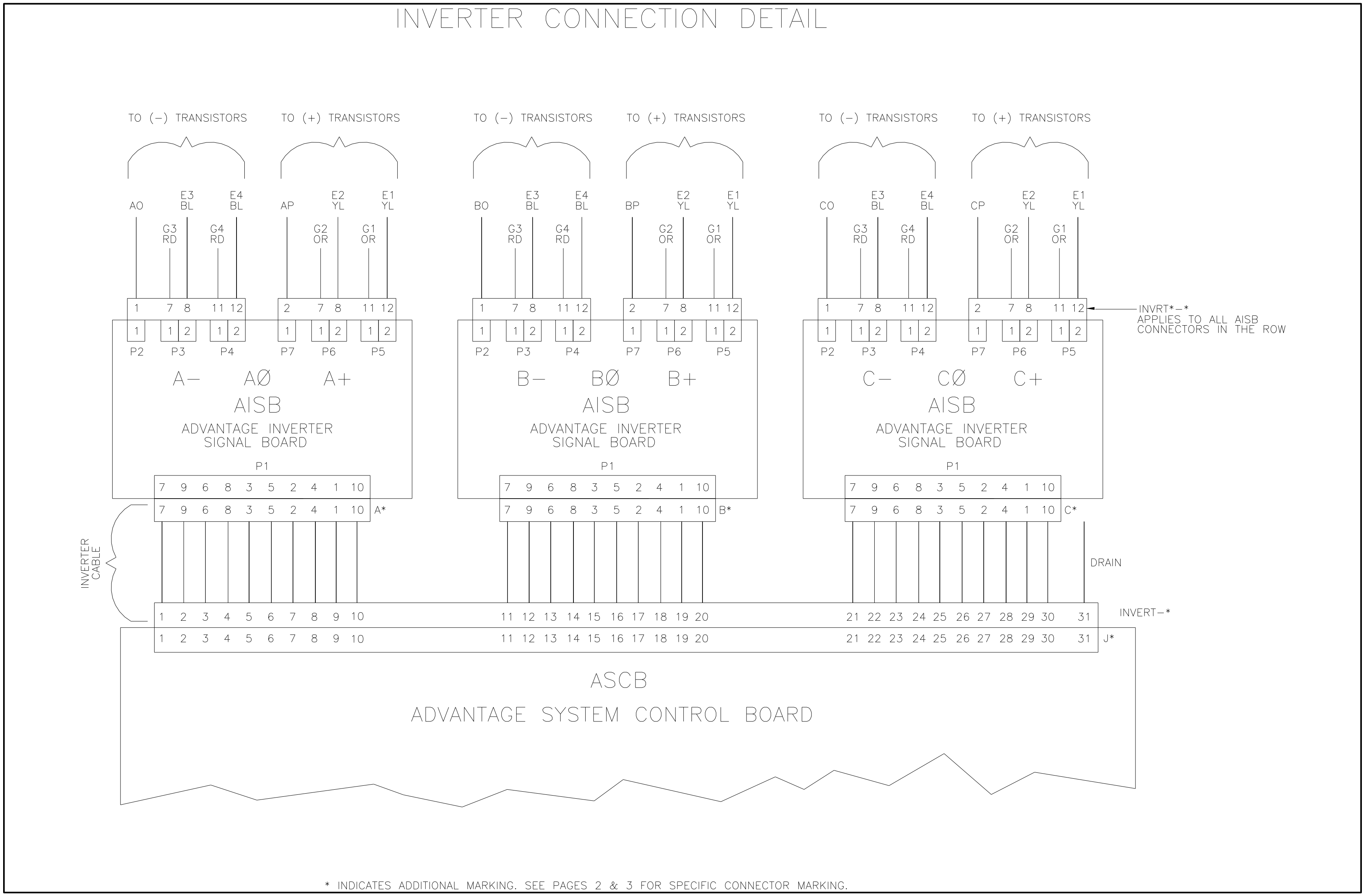


Figure 57: ADVANTAGE 8000 NEMA4 6/12 PULSE DETAIL: INVERTER BOARD CONNECTIONS
Drawing Number: 908264 - Sheet Number:5 - Revision: A - Revision Date: 18OCT12

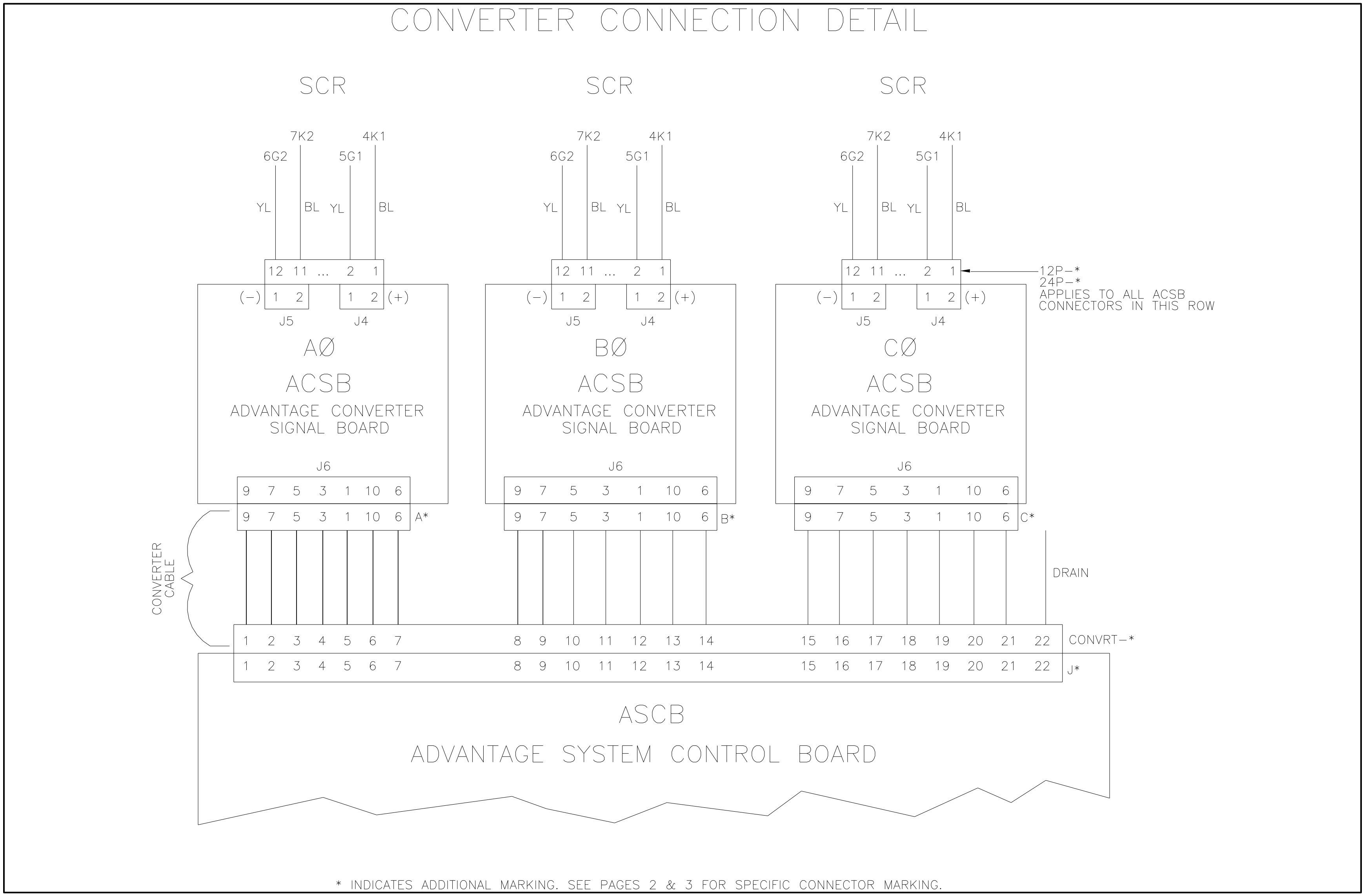
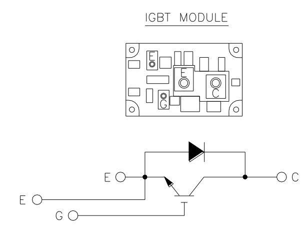
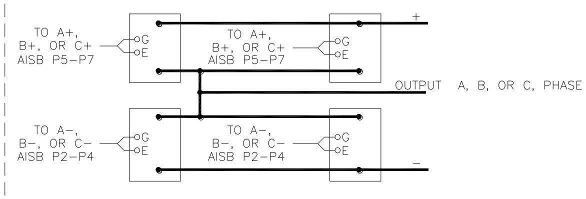


Figure 58: ADVANTAGE 8000 NEMA4 6/12 PULSE DETAIL: CONVERTER BOARD CONNECTIONS
Drawing Number: 908264 - Sheet Number: 6 - Revision: A - Revision Date: 18OCT12



DETAIL "E"

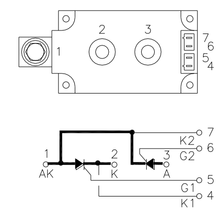


SINGLE DEVICE MODULES IN SERIES/PARALLEL

DETAIL "D"

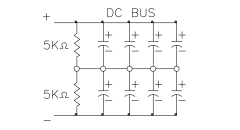
NOTES:

1. SEE DETAIL "A" FOR SCR MODULE TERMINAL IDENTIFICATION.
2. THE NUMBER LINK INDUCTOR IS DETERMINED BY THE VSC RATING. THE 8000 SERIES HAS PAIRS OF PARALLEL INDUCTORS. SEE CHART 1 BELOW.
3. THE BUS CAPACITANCE CONSISTS OF PAIRS OF CAPACITORS IN SERIES TO ATTAIN THE REQUIRED VOLTAGE RATINGS. BLEEDER RESISTORS ARE PLACED IN PARALLEL WITH EACH CAPACITOR MODULE CONSISTING OF 4 PAIRS OF CAPACITORS. THE RESISTORS ARE CONTAINED WITHIN THE CAPACTOR MODULE. THE RESISTORS INSURE THE VOLTAGE IS EQUALLY DIVIDED ACROSS THE CAPACITOR MODULE. MULTIPLE CAPACITOR MODULES ARE USED IN PARALLEL TO OBTAIN THE OVERALL CAPACITANCE REQUIRED. THIS CAPACITANCE IS DETERMINED BY THE VSC RATING. SEE CHART 1 BELOW FOR THE NUMBER OF MODULES REQUIRED. SEE SCHEMATIC DETAIL "B".
4. IGBT MODULES ARE USED IN SERIES AND PARALLEL TO ACHIEVE THE REQUIRED RATINGS. THIS SCHEMATIC SHOWS ONE MODULE PER PHASE. MODULES ARE CONNECTED AS SHOWN IN SCHEMATIC DETAIL "D". SEE DETAIL "E" FOR IGBT MODULE TERMINAL IDENTIFICATION. SEE CHART 1 BELOW.



SCR MODULE

DETAIL "A"



BUS CAPACITOR MODULE SCHEMATIC

DETAIL "B"

QUANTITIES SHOWN FOR THE 8000 SERIES ARE THE SUM OF THE LEFT AND RIGHT DRIVE SECTIONS
ALL 24 PULSE DRIVES HAVE A TOTAL OF 12 SCRS & ADVANTAGE CONVERTER SIGNAL BOARD (ACSB)
ALL 24 PULSE DRIVES HAVE 4 DIODE MODULES

CHART 1

MODEL	IGBT TYPE	IGBT PER PHASE	INDUCTORS			CAPACTOR MODULES	CT RATIO	FUSES	FANS	HEATSINK TEMP SENSORS	AUX BUS CAPACTORS 5 MFD
			200A	100A	50A						
8600	400A	8	4	2	0	10	2000:1	500A	4	4	24
8700	400A	8	6	0	0	12	2000:1	600A	4	4	24
8800	600A	8	6	0	2	14	2000:1	700A	4	4	24
8900	600A	8	8	0	0	16	2000:1	800A	4	4	24

Figure 59: ADVANTAGE 8000 NEMA4 6/12 PULSE DETAIL: IGBT, SCR, DIODE, DC BUS
Drawing Number: 908264 - Sheet Number:7 - Revision: A - Revision Date:18OCT12

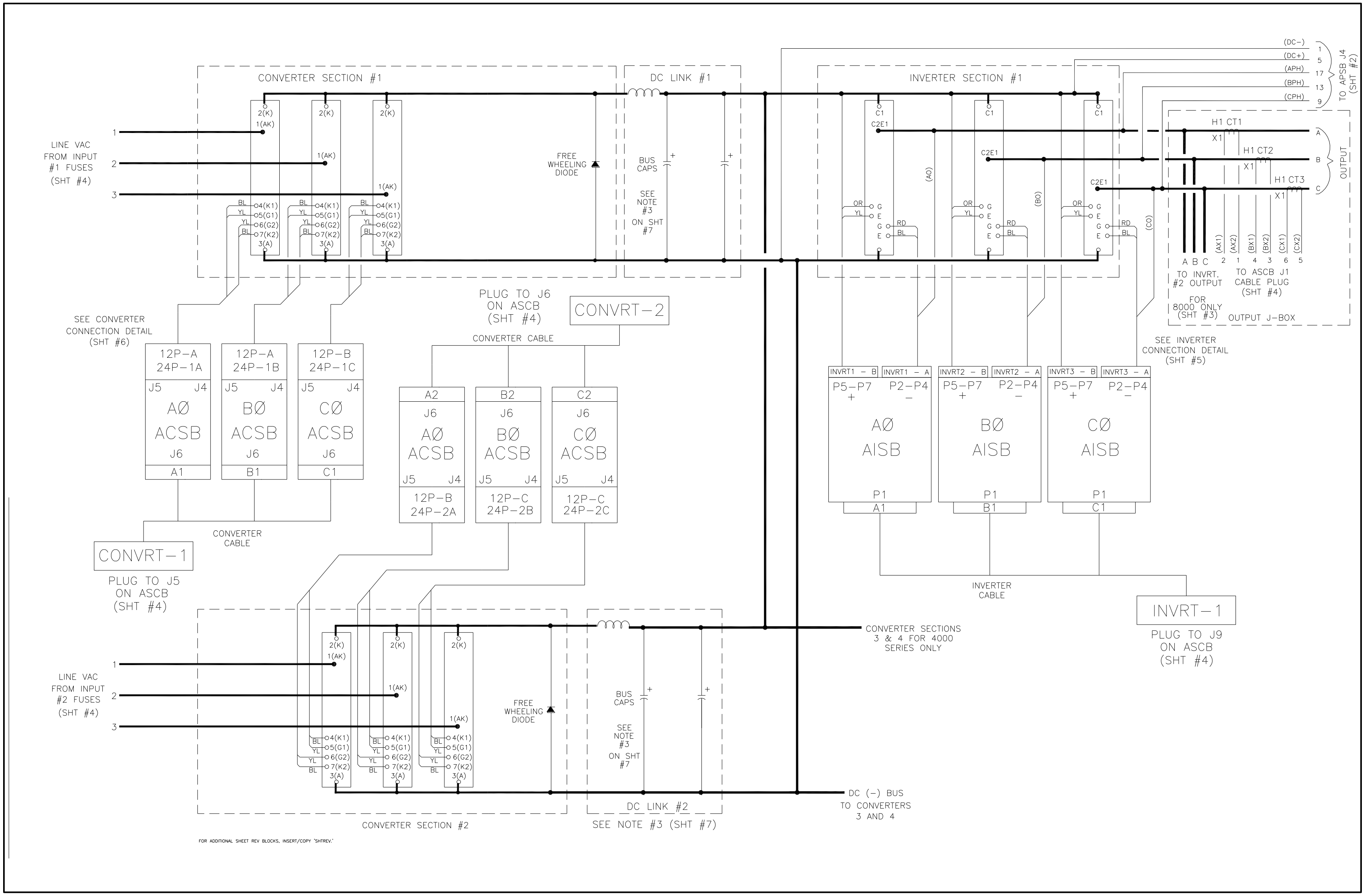


Figure 60: ADVANTAGE 8000 NEMA4 6/12 PULSE DETAIL: CONVERTER 1 & 2 AND INVERTER 1

Drawing Number:908182 - Sheet Number:2 - Revision: A - Revision Date:18OCT12

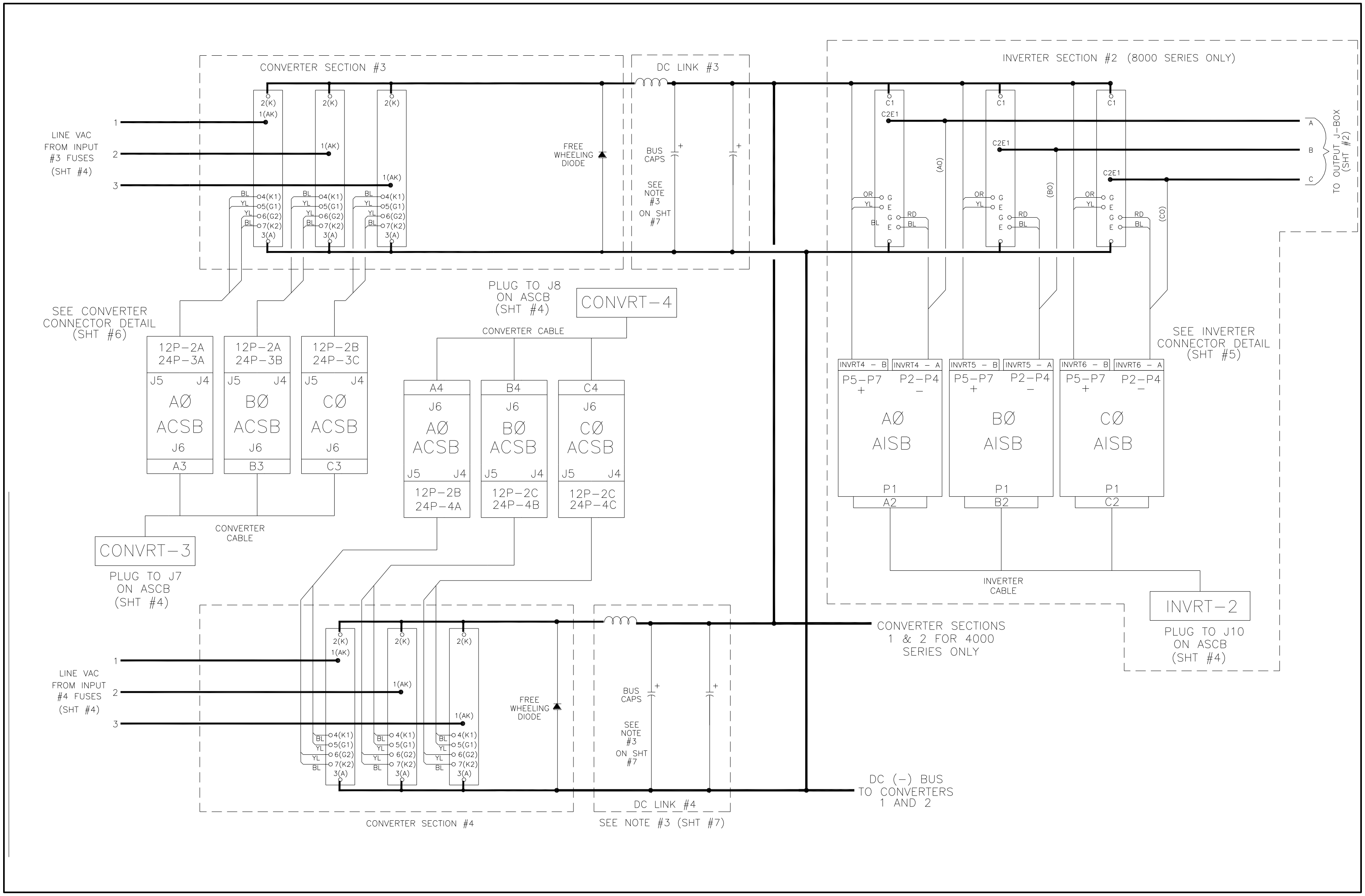


Figure 61: ADVANTAGE 4000/ 8000 NEMA4 6/12 PULSE DETAIL: CONVERTER 3 & 4 AND INVERTER 2
Drawing Number:908182 - Sheet Number:3 - Revision: A - Revision Date:18OCT12

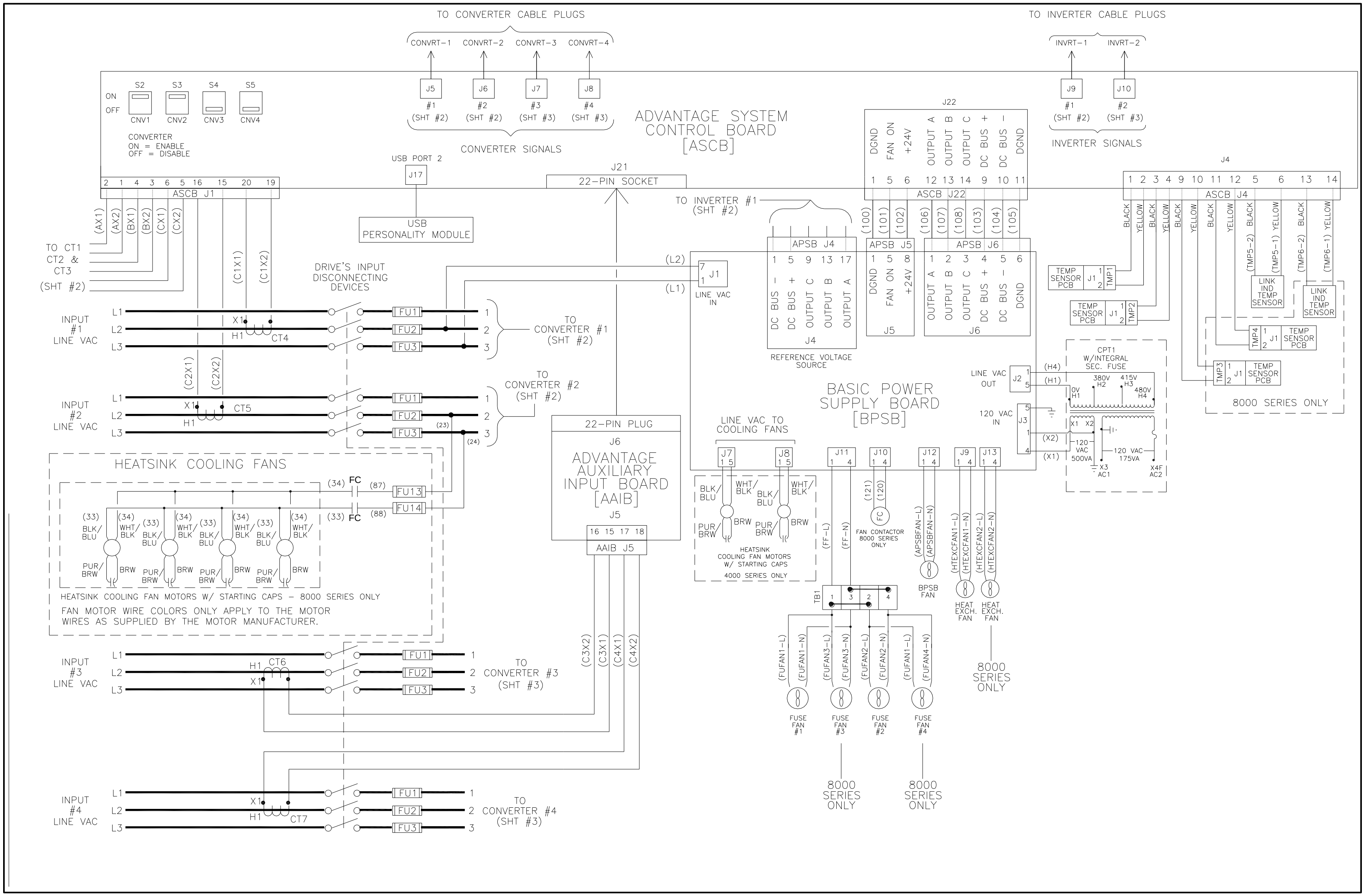


Figure 62: ADVANTAGE 4000/8000 NEMA4 24 PULSE CONTROL BOARD, POWER SUPPLY, COOLING FANS
Drawing Number: 908182 - Sheet Number: 4 - Revision: A - Revision Date: 18OCT12

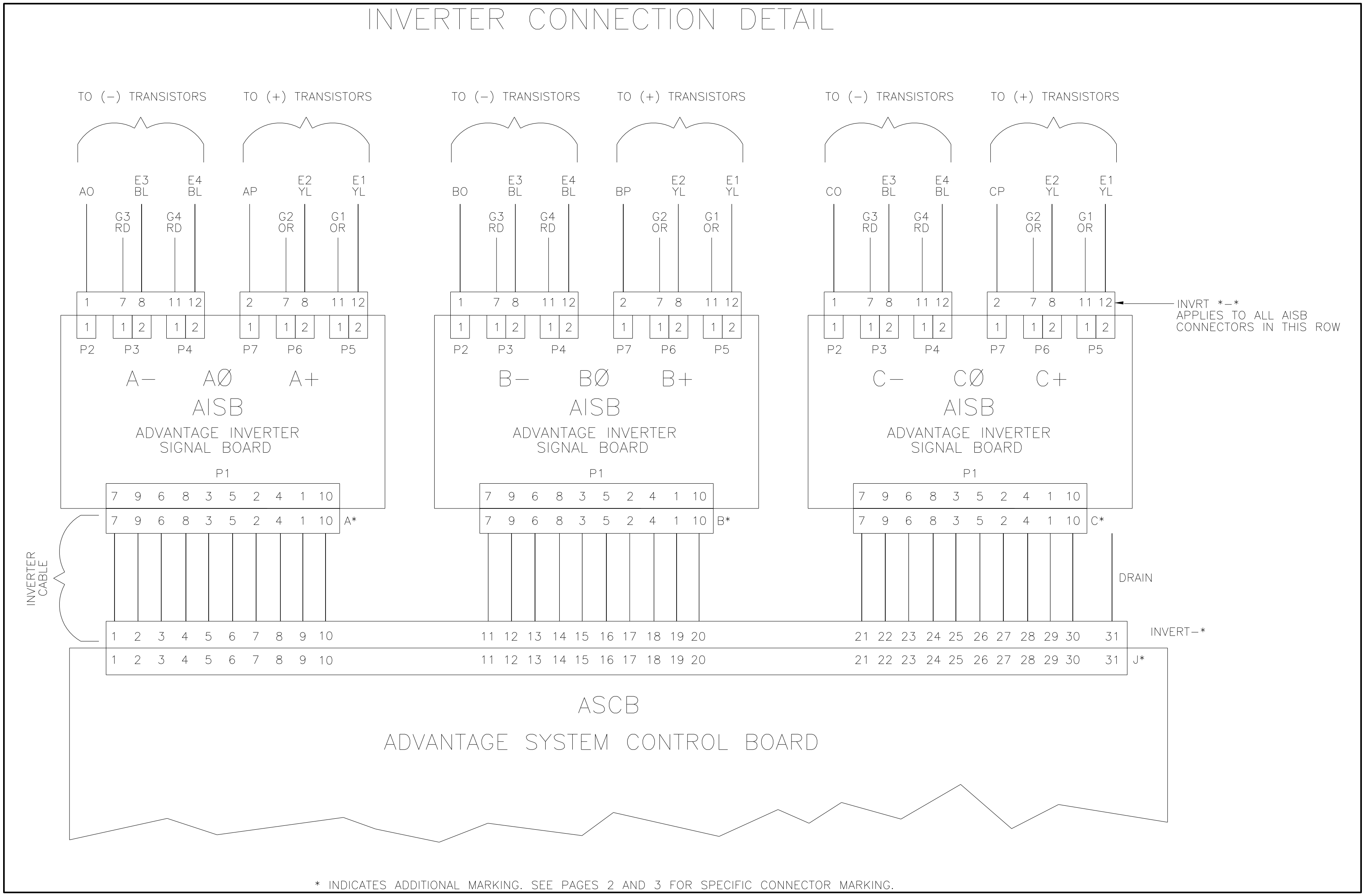


Figure 63: ADVANTAGE 4000/ 8000 NEMA4 24 PULSE Detail: Inverter Board Connections
Drawing Number: 908182 - Sheet Number: 5 - Revision: A - Revision Date: 18OCT12

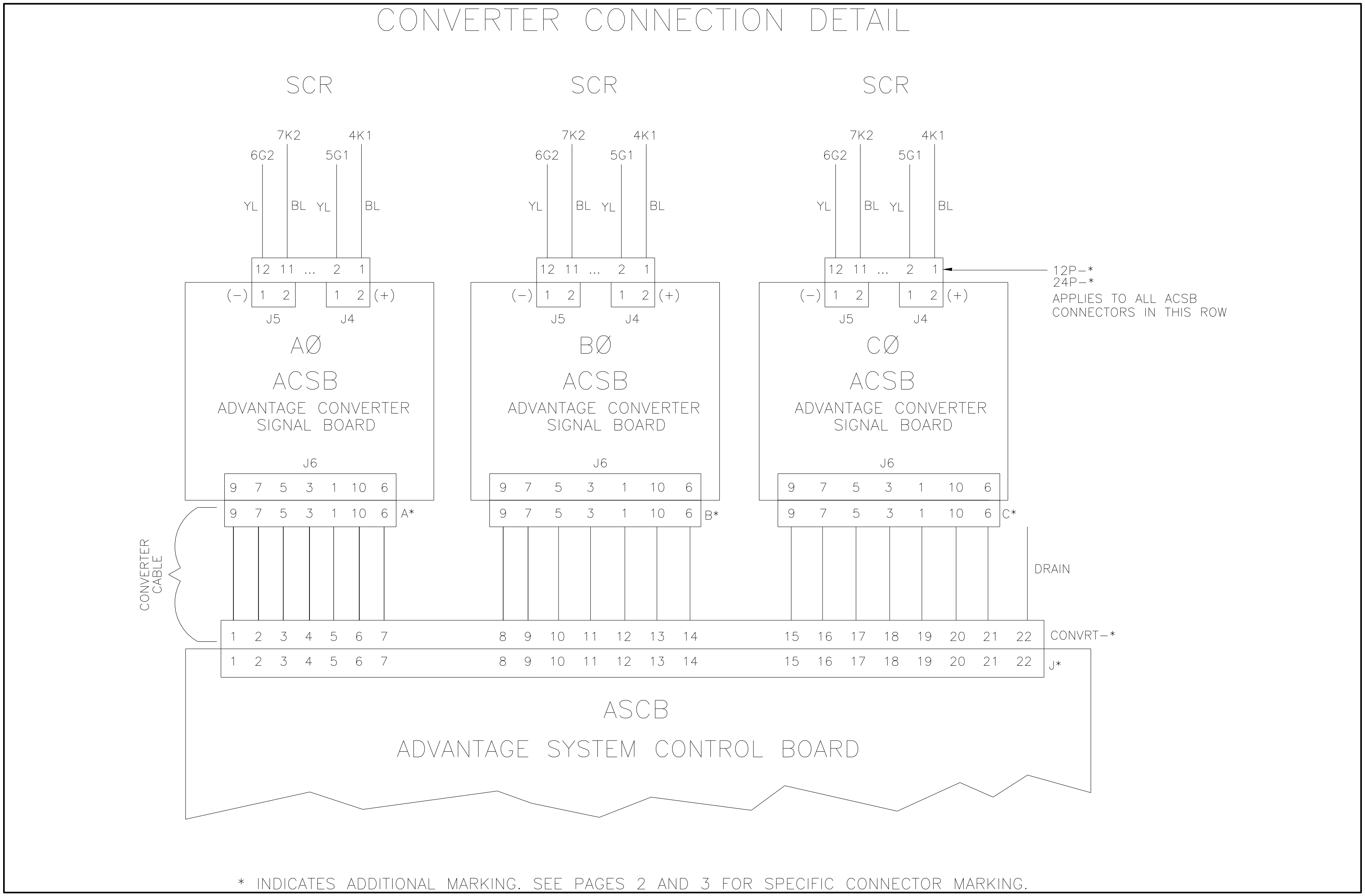
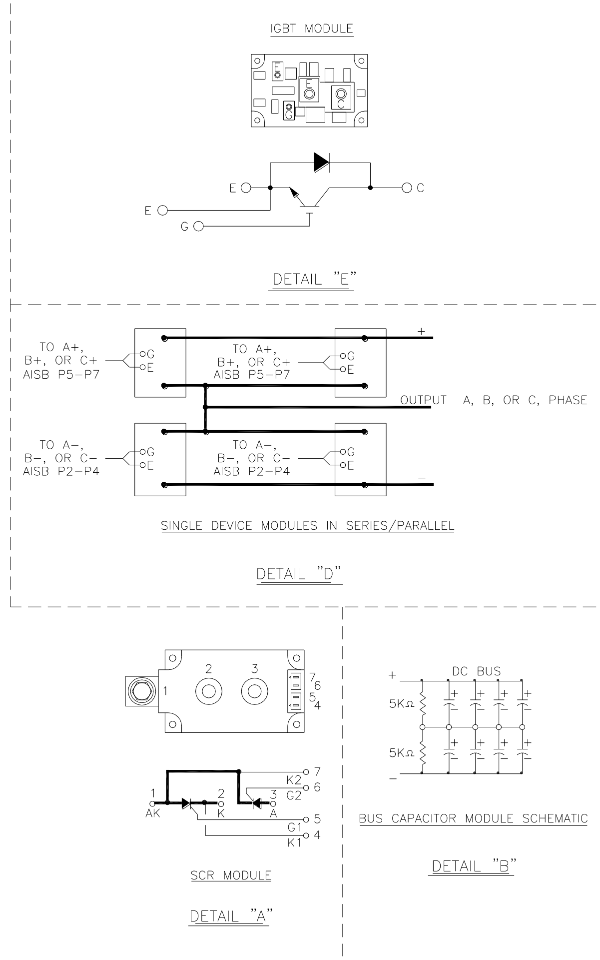


Figure 64: ADVANTAGE 4000/ 8000 NEMA4 24 PULSE DETAIL: CONVERTER BOARD CONNECTIONS
Drawing Number: 908182 - Sheet Number: 6 - Revision: A - Revision Date: 18OCT12



NOTES:

1. SEE DETAIL "A" FOR SCR MODULE TERMINAL IDENTIFICATION.
2. THE NUMBER LINK INDUCTOR IS DETERMINED BY THE VSC RATING. THE 8000 SERIES HAS PAIRS OF PARALLEL INDUCTORS. SEE CHART 1 BELOW.
3. THE BUS CAPACITANCE CONSISTS OF PAIRS OF CAPACITORS IN SERIES TO ATTAIN THE REQUIRED VOLTAGE RATINGS. BLEEDER RESISTORS ARE PLACED IN PARALLEL WITH EACH CAPACITOR MODULE CONSISTING OF 4 PAIRS OF CAPACTORS. THE RESISTORS ARE CONTAINED WITHIN THE CAPACTOR MODULE. THE RESISTORS INSURE THE VOLTAGE IS EQUALLY DIVIDED ACROSS THE CAPACITOR MODULE. MULTIPLE CAPACITOR MODULES ARE USED IN PARALLEL TO OBTAIN THE OVERALL CAPACITANCE REQUIRED. THIS CAPACITANCE IS DETERMINED BY THE VSC RATING. SEE CHART 1 BELOW FOR THE NUMBER OF MODULES REQUIRED. SEE SCHEMATIC DETAIL "B".
4. IGBT MODULES ARE USED IN SERIES AND PARALLEL TO ACHIEVE THE REQUIRED RATINGS. THIS SCHEMATIC SHOWS ONE MODULE PER PHASE. MODULES ARE CONNECTED AS SHOWN IN SCHEMATIC DETAIL "D". SEE DETAIL "E" FOR IGBT MODULE TERMINAL IDENTIFICATION. SEE CHART 1 BELOW.

QUANTITIES SHOWN FOR THE 8000 SERIES ARE THE SUM OF THE LEFT AND RIGHT DRIVE SECTIONS
ALL 24 PULSE DRIVES HAVE A TOTAL OF 12 SCRS & ADVANTAGE CONVERTER SIGNAL BOARD (ACSB)
ALL 24 PULSE DRIVES HAVE 4 DIODE MODULES

CHART 1

MODEL	IGBT TYPE	IGBT PER PHASE	INDUCTORS 200A	INDUCTORS 100A	INDUCTORS 50A	CAPACITOR MODULES	CT RATIO	FUSES	FANS	HEATSINK TEMP SENSORS	AUX BUS CAPACITORS 5 MFD
4300, 4350	400A	4	4	0	0	8	500:1	150A	2	2	12
4400, 4500	400A	4	4	0	0	8	1000:1	200A	2	2	12
8600	400A	8	4	0	4	10	2000:1	250A	4	4	24
8700	400A	8	4	4	0	12	2000:1	300A	4	4	24
8800	600A	8	8	0	0	16	2000:1	350A	4	4	24
8900	600A	8	8	0	0	16	2000:1	400A	4	4	24

Figure 65: ADVANTAGE 4000/ 8000 NEMA4 24 PULSE DETAIL: IGBT, SCR, DIODE, DC BUS
Drawing Number: 908182 - Sheet Number: 7 - Revision: A - Revision Date: 18OCT12

11 Outline and Anchor Dimensional Drawings

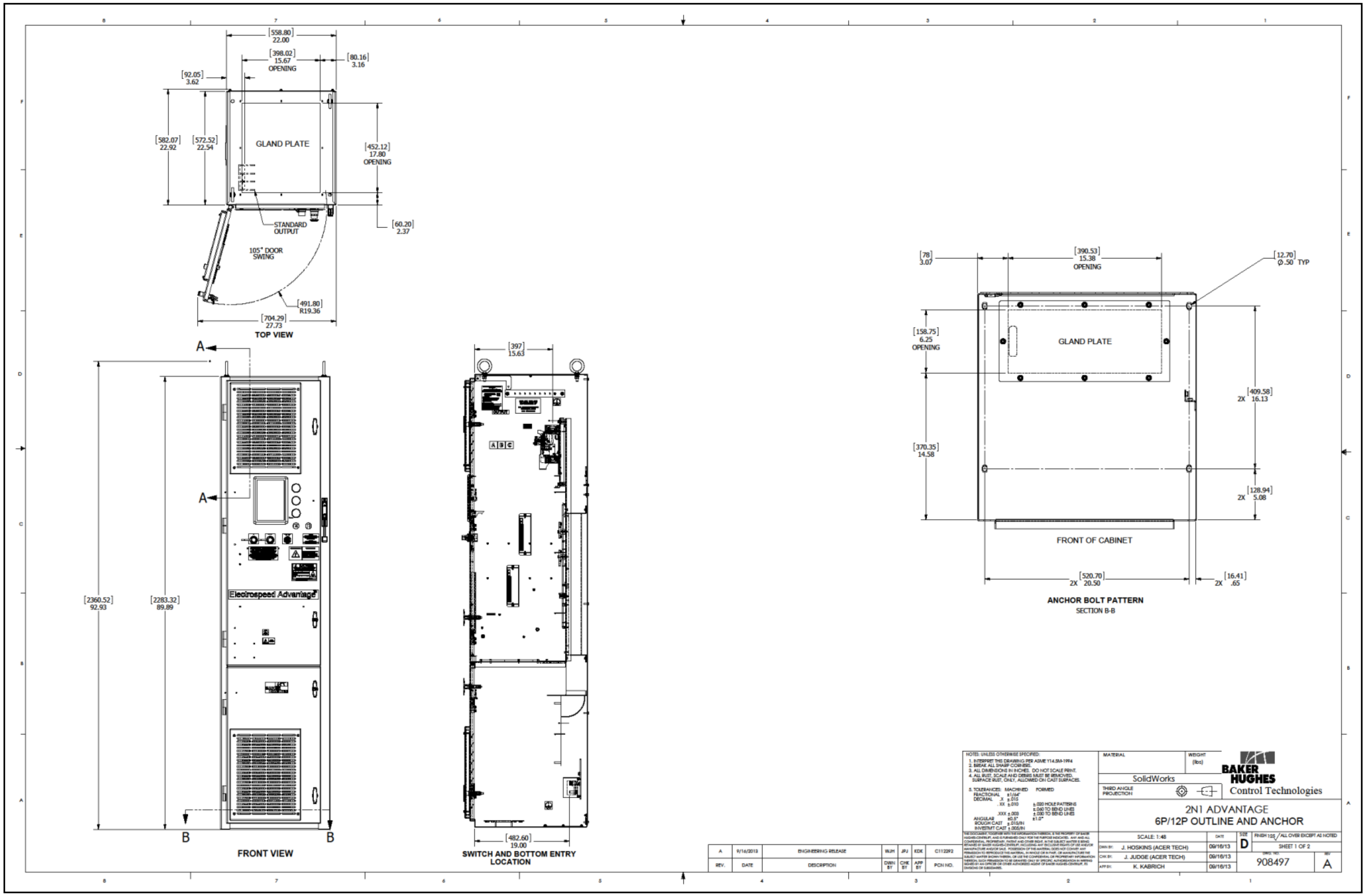


Figure 66: ADVANTAGE 2000 NEMA 1: OUTLINE & ANCHOR DIMENSIONAL DIAGRAMS
Drawing Number: 908497 - Sheet Number: 1 - Revision: A - Revision Date: 16SEP13

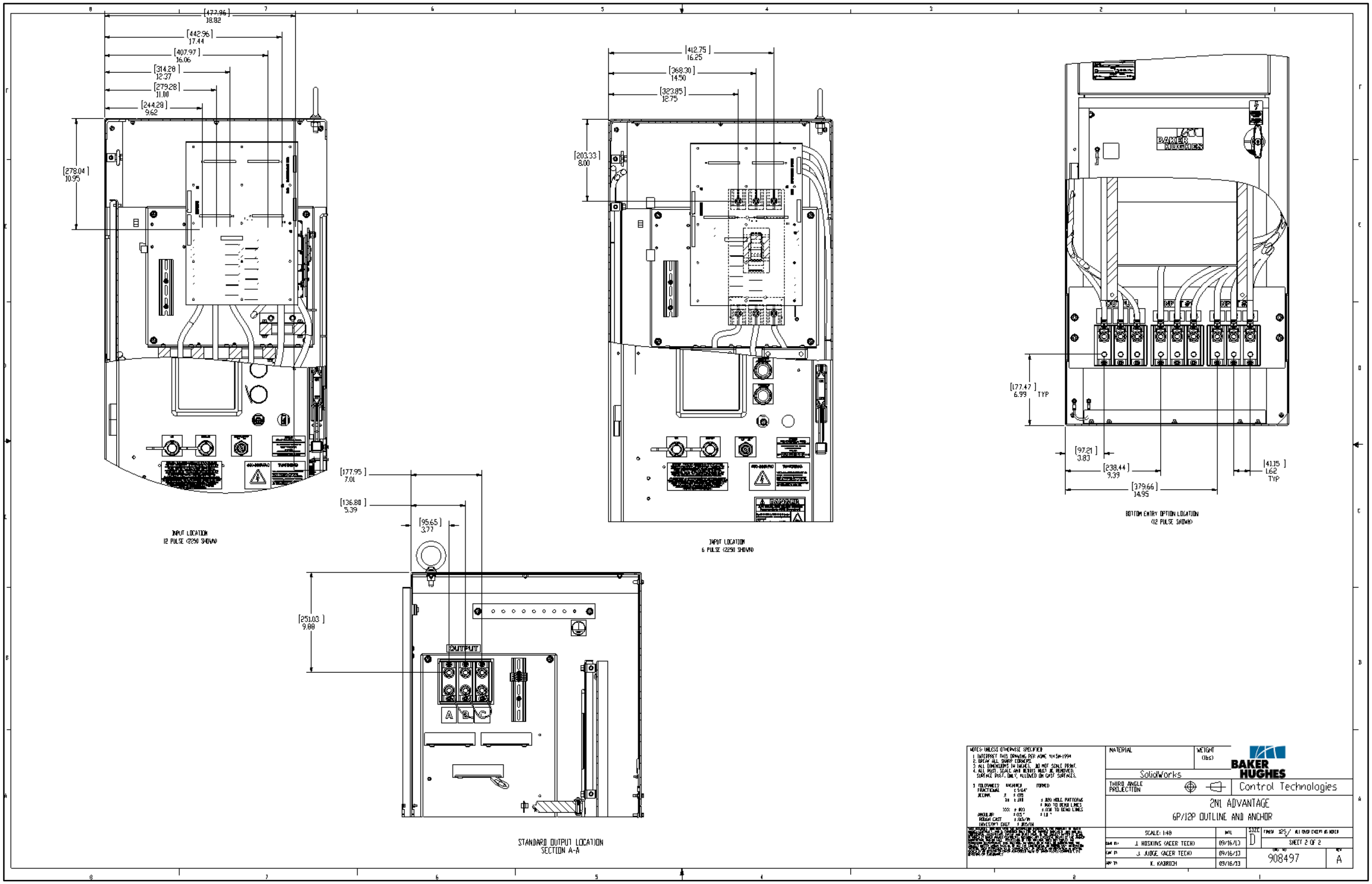


Figure 67: ADVANTAGE 2000 NEMA 1: OUTLINE & ANCHOR DIMENSIONAL DIAGRAMS
Drawing Number: 908497 - Sheet Number: 2 - Revision: A - Revision Date: 16SEP13

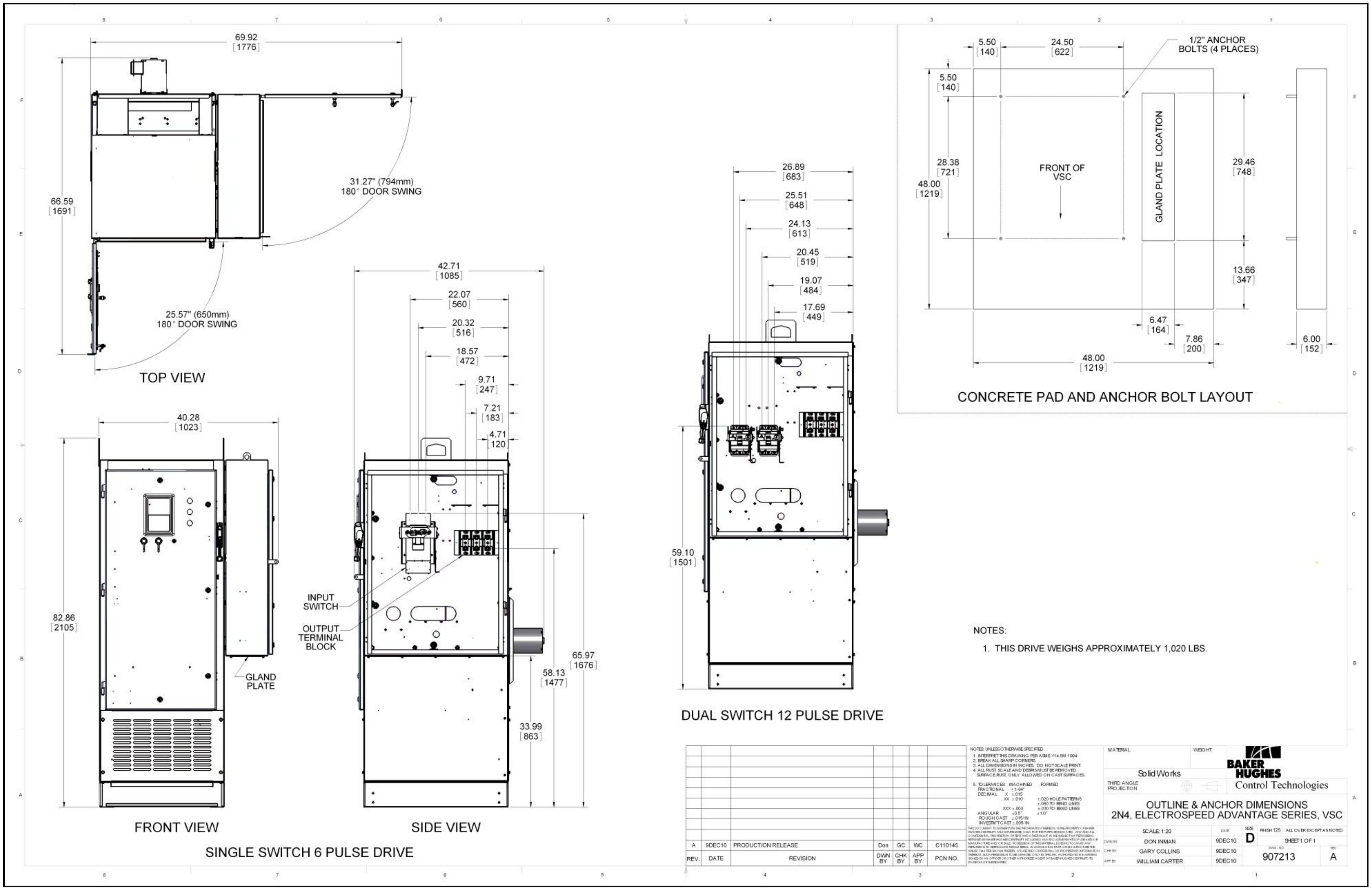


Figure 68: ADVANTAGE 2000 NEMA 4: OUTLINE & ANCHOR DIMENSIONAL DIAGRAMS

Drawing Number: 907213 - Sheet Number: 1 - Revision: A - Revision Date: 9DEC10

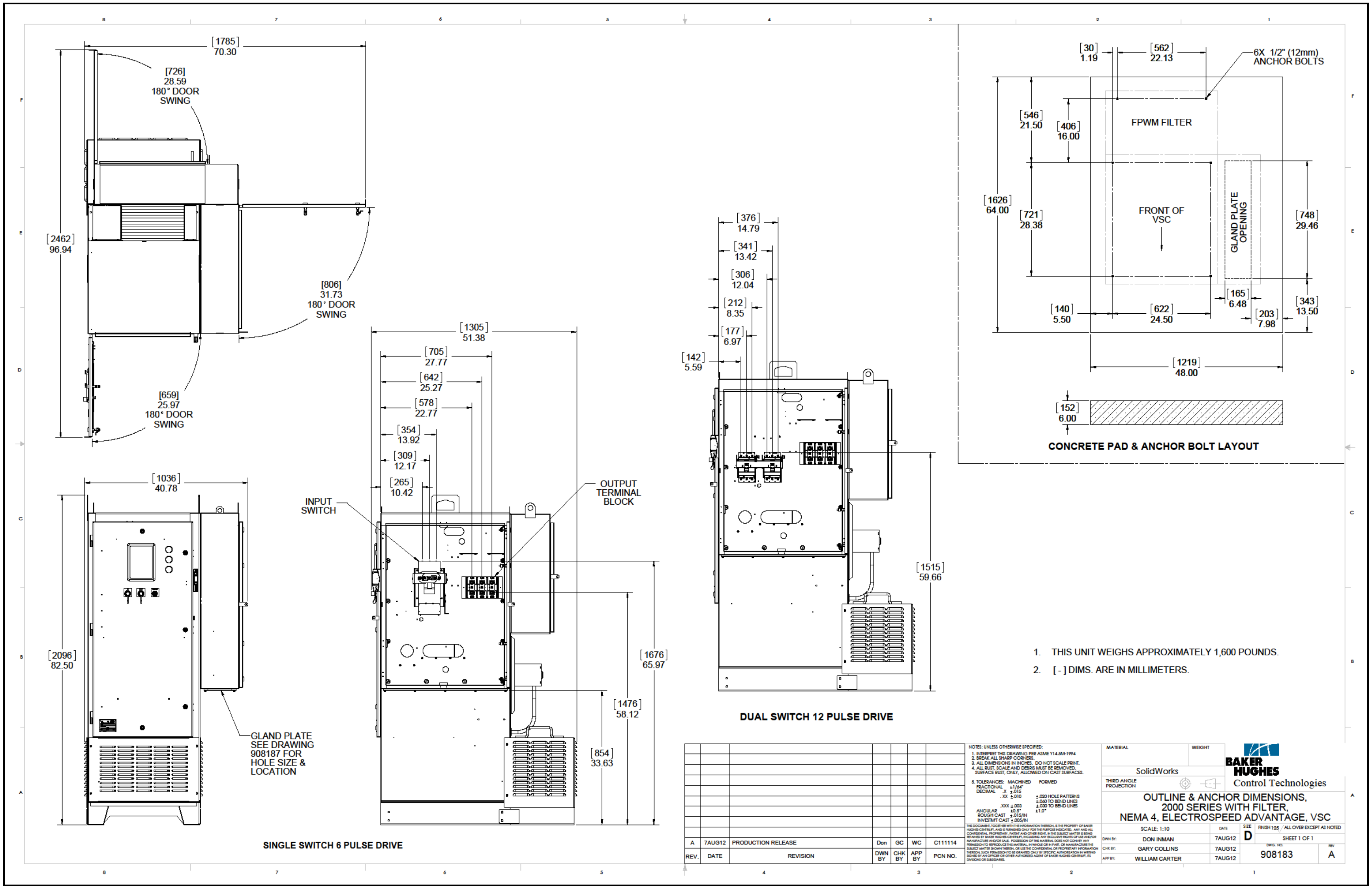


Figure 69: ADVANTAGE 2000 NEMA 4 SERIES WITH PWM FILTER OUTLINE & ANCHOR DIMENSIONAL DIAGRAMS
Drawing Number: 908183 - Sheet Number: 1 - Revision: A - Revision Date: 7AUG12

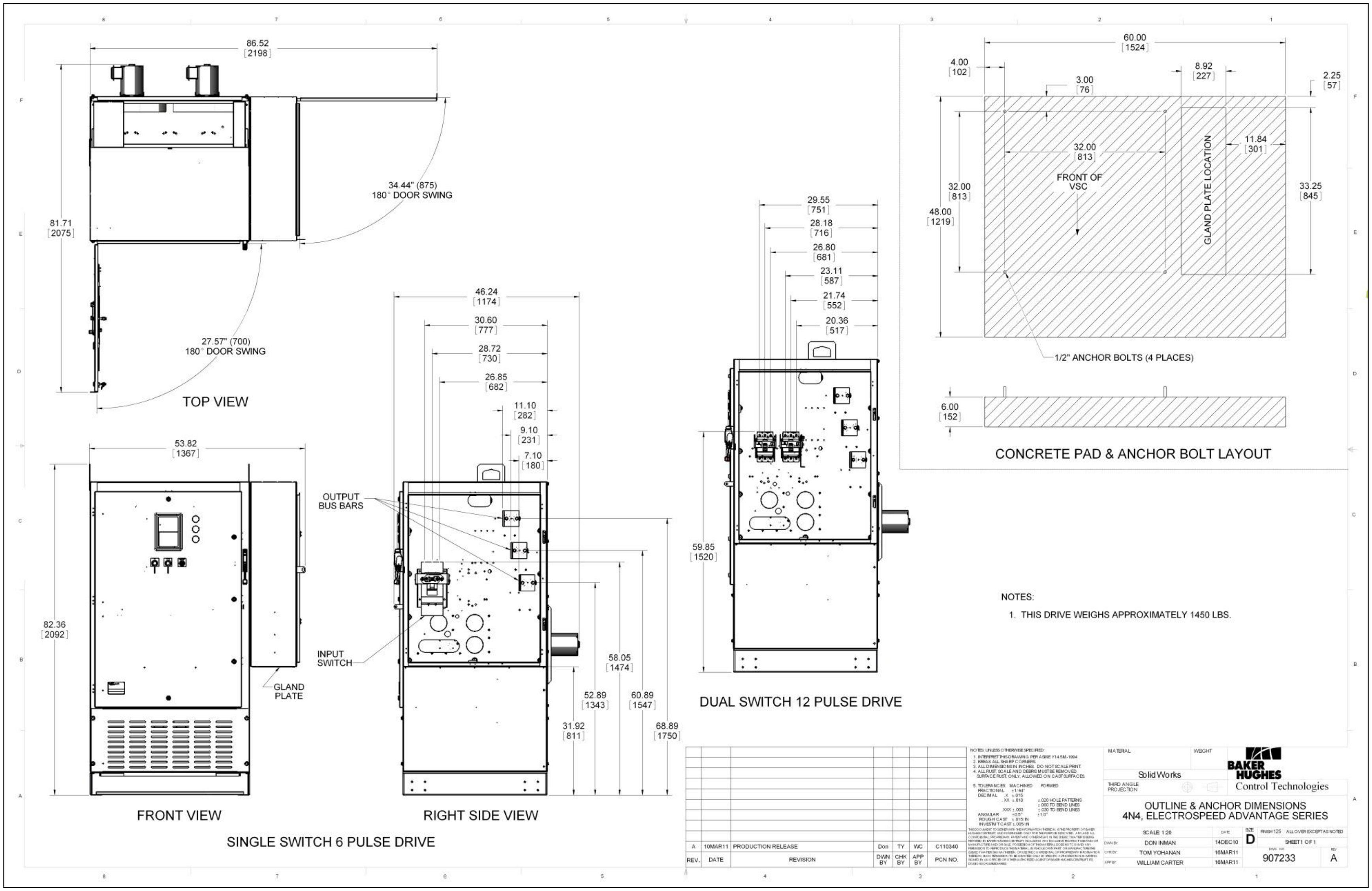


Figure 70: ADVANTAGE 4000 NEMA 4 6/12P SERIES OUTLINE & ANCHOR DIMENSIONAL DIAGRAMS

Drawing Number: 907233 - Sheet Number: 1 - Revision: A - Revision Date: 16MAR11

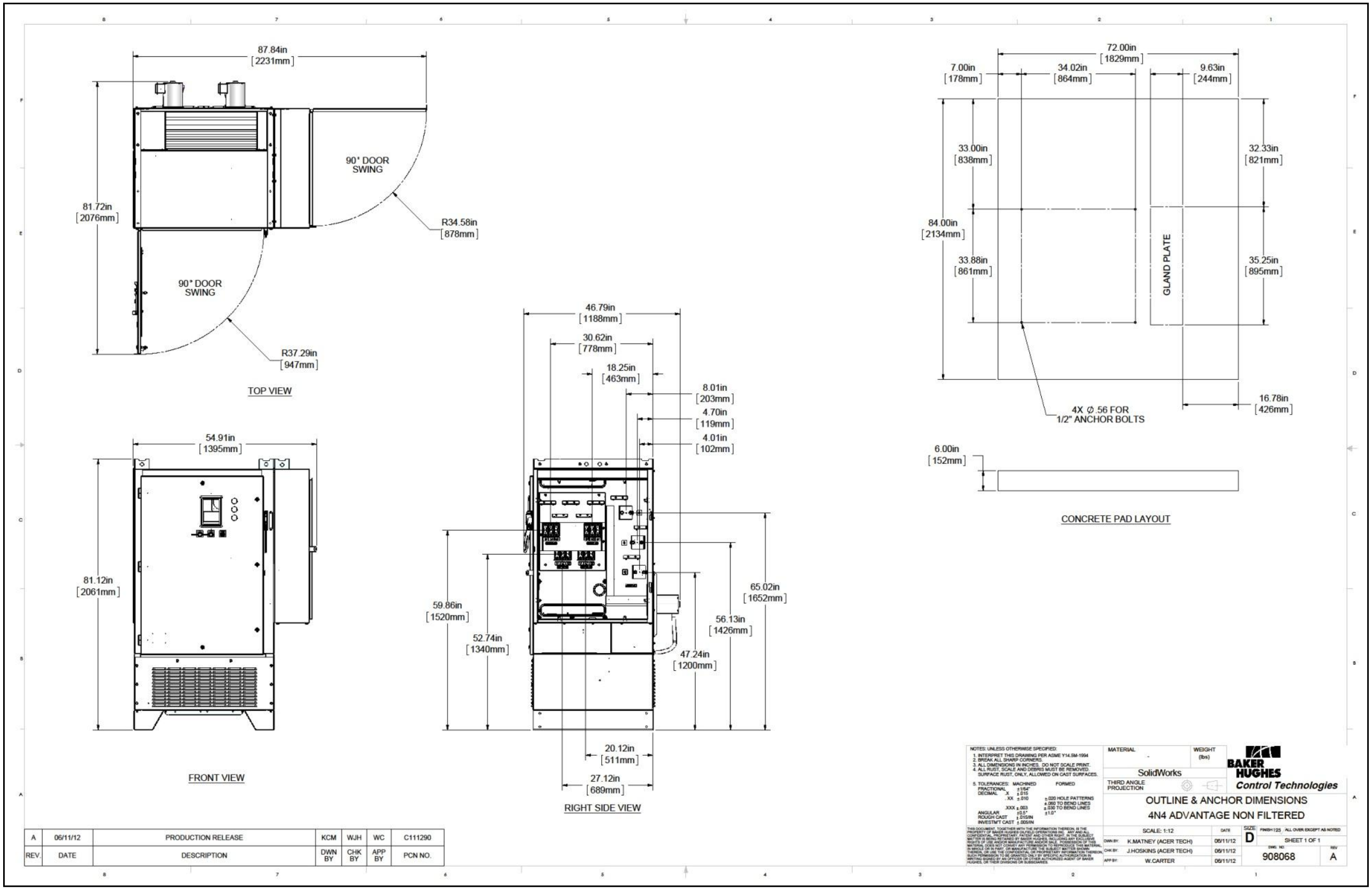


Figure 71: ADVANTAGE 4000 NEMA 4 24P SERIES OUTLINE & ANCHOR DIMENSIONAL DIAGRAMS
Drawing Number: 908068 - Sheet Number: 1 - Revision: A - Revision Date: 11JUN12

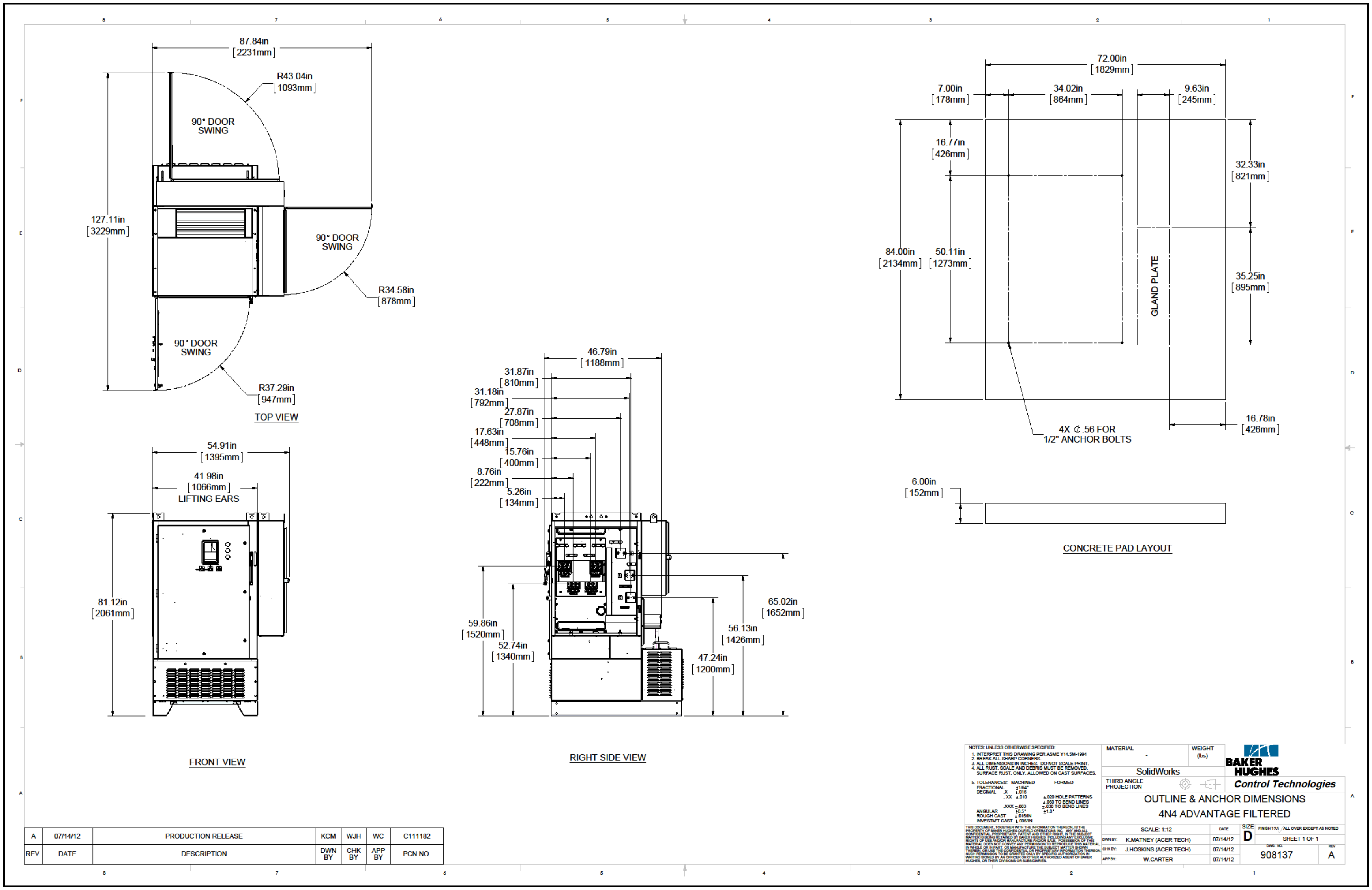


Figure 72: ADVANTAGE 4000 NEMA 4 SERIES WITH PWM FILTER OUTLINE & ANCHOR DIMENSIONAL DIAGRAMS

Drawing Number: 908137- Sheet Number: 1 - Revision: A - Revision Date: 17JUN12

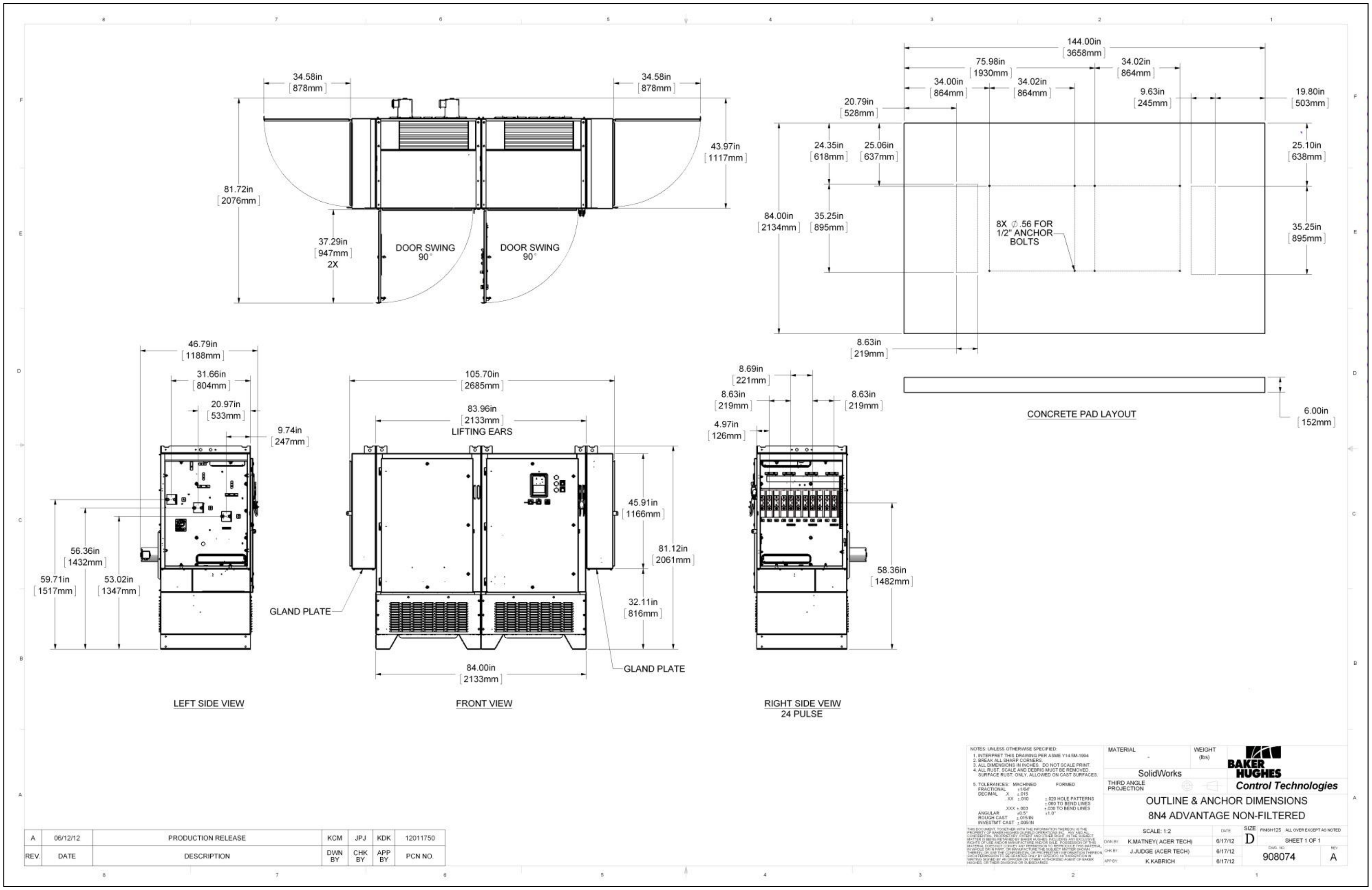


Figure 73: ADVANTAGE 8000 NEMA 4 SERIES OUTLINE & ANCHOR DIMENSIONAL DIAGRAMS
Drawing Number: 908074 - Sheet Number: 1 - Revision: A - Revision Date: 17JUN12

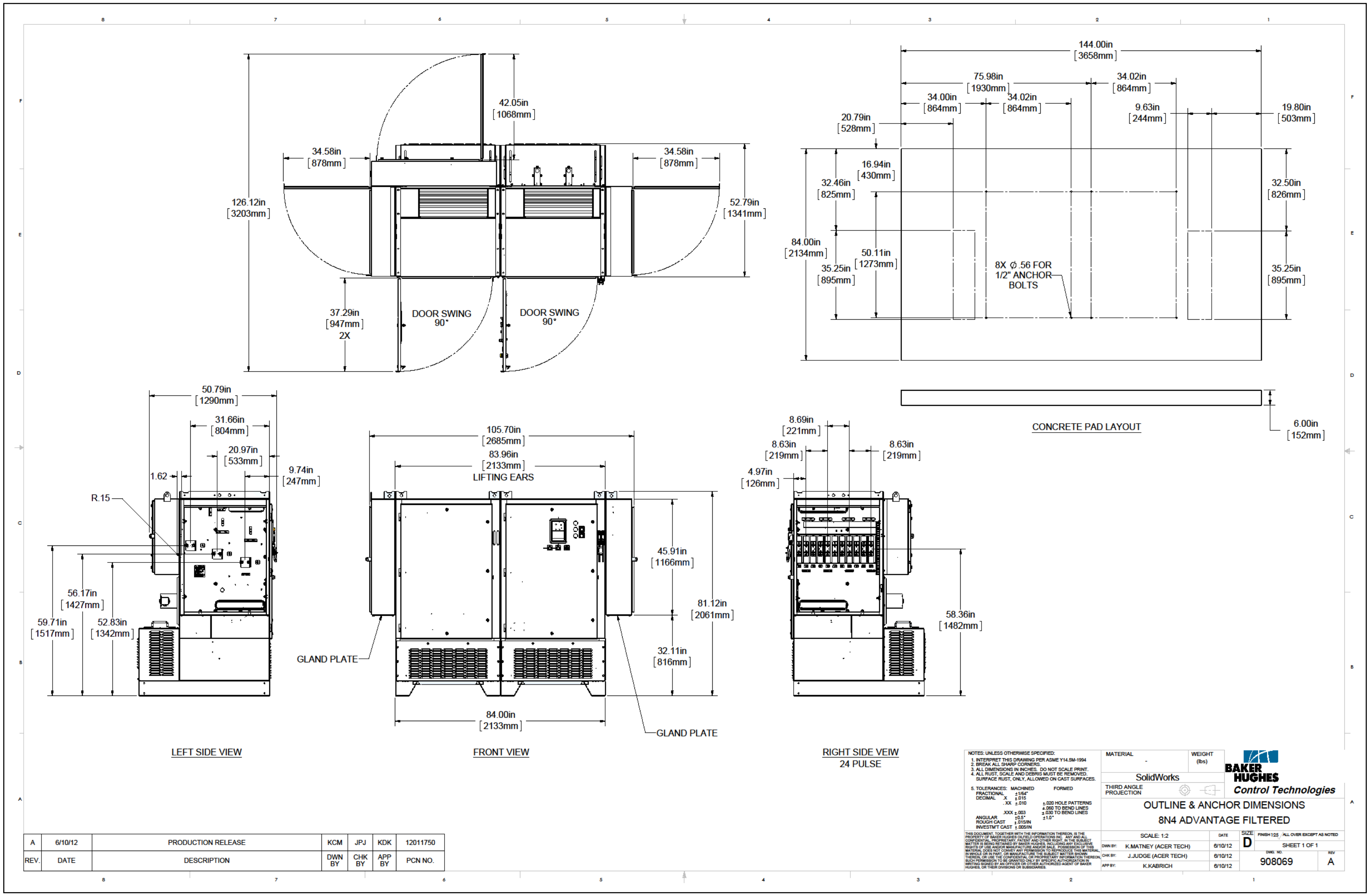


Figure 74: ADVANTAGE 8000 NEMA 4 SERIES WITH PWM FILTER OUTLINE & ANCHOR DIMENSIONAL DIAGRAMS

Drawing Number: 908069 - Sheet Number: 1 - Revision: A - Revision Date: 10JUN12

12 Recommended Spare Parts

PART NO.	QTY CODE	DESCRIPTION	VSC SERIES	Prior Model	
	BASE/MO/YR	*For calculating quantities, see instructions at end of list.*		Part Numbers	
				GCS	ICS
SEMICONDUCTORS					
900545	B4/ M.2/ Y.4	IGBT 600A	2250/ 4400/ 4500/ 8800/ 8900	X	
900546	B4/ M.2/ Y.4	IGBT 400A	2125/ 2200/ 4300/ 4350/ 8600/ 8700	X	
900547	B1/ M.1/ Y.2	IGBT 200A	2060	X	
88465	B1/ M.1/ Y.2	SCR, 250A	2000/ 4000/ 8000	X	X
89052	B1/ M.1/ Y.2	DIODE,95A	2000	X	X
88523	B1/ M.1/ Y.2	DIODE 260A	4000/ 8000	X	X
CIRCUIT BOARDS					
906610	B1/ M.1/ Y.5	(BSCB) BASIC SYS CNTRL BD NRTL	2000 / 4000		
902129 (PKG)	B3/ M.3/ Y.6	(CSB) CONV. SIG BD NRTL	2000 / 4000	X	
902130 (PKG)	B6/ M.4/ Y.8	(ISB) INVERTER SIGNAL BD NRTL	2000 / 4000	X	
906641	B1/ M.1/ Y.2	(BPSB) ADV BASIC PWR SPLY BD NRTL (OLD)	2000 / 4000		
57983	B2/ M.1/ Y.2	(TSB) TEMPERATURE SENSING BD	2000 / 4000 / 8000	X	
58161	B1/ M.1/ Y.2	SNUBBER BD	2000 / 4000 / 8000	X	
907017 (PKG)	B1/ M.1/ Y.2	(AGDB) ADV GRAPHICS DSPLY BD	2000 / 4000 / 8000		
904599	B1/ M0/ Y.5	BEZEL & KEYPAD ADV GRAPHICS DSPLY	2000 / 4000 / 8000		
908241	B1/ M.1/ Y.2	(BPSB) ADV BASIC PWR SPLY BD NRTL (NEW)	2000/ 4000/ 8000		
904366	B6/ M.4/ Y.8	(ACSB) ADV CONVERTER SIGNALS BD NRTL	4000 24P/ 8000		
904843	B6/ M.4/ Y.8	(ASCB) ADVANTAGE SYSTEM CONTROL BD NRTL	4000 24P/ 8000		
905756	B6/ M.4/ Y.8	(AISB) ADVANTAGE INVERTER SIGNALS BD NRTL	4000 24P/ 8000		
908241	B6/ M.4/ Y.8	(BPSB) ADV BASIC PWR SPLY BD NRTL NEW	2000 / 4000 / 8000		

PART NO.	QTY CODE	DESCRIPTION		VSC SERIES	Prior Model	
	BASE/MO/YR	*For calculating quantities, see instructions at end of list.*			Part Numbers	
					GCS	ICS
MAGNETICS (LINK REACTOR)						
902251	B1/ M.05/Y.05	INDUCTOR 200A 0.75mH	**Nema 4**	200 6P/ 4350 12P	X	
				2075 6P/ 2100 6P		
				2125 6P/ 2150 6P/ 2200 6P		
				2250 6P/ 2150 12P/ 2200 12P		
				2250 12P/ 4000 6P		
				4300-4500 24P / 8600-8900 24P		
902250	B1/ M.05/Y.05	INDUCTOR, 100A, 1.5mH	**Nema 4**	2060 6P/ 2150 6P	X	
				2200 6P/ 4300 6P/ 4400 6P		
				2075 12P/ 2100 12P/ 8600/ 8800		
				2125 12P/ 4350 12P		
				4150- 4250 24P/ 8700 24P		
902249	B1/M.05/Y.05	INDUCTOR 50A, 3mH	Nema 4	2060 12P/4300 12P/4050-4125 24P/8600 24P	X	
900527	B1/M.05/Y.05	INDUCTOR 200A, 0.75mH	Nema 1	2000 6P		
				2075 6P / 2100 6P		
				2125 6P / 2150 6P		
				2250 6P / 2150 12P / 2200 12P		
				2250 12P		
900414	B1/ M.05/Y.05	INDUCTOR, 100A, 1.5mH	**Nema 1**	2060 6P/ 2150 6P		
				2200 6P		
				2075 12P/ 2100 12P		
				2125 12P		

PART NO.	QTY CODE	DESCRIPTION	VSC SERIES	Prior Model	
	BASE/MO/YR	*For calculating quantities, see instructions at end of list.*		Part Numbers	
				GCS	ICS
900154	B1/ M.05/Y.05	INDUCTOR 50A, 3mH Nema 1	2060 12P		
CAPACITORS					
58904	B1/ M.1/ Y.2	BUS CAPACITOR MODULE	2000/ 4000/ 8000	X	
900798	B1/ M.1/ Y.2	CAPACITOR, 1500MFD	2000/ 4000/ 8000	X	
903817	B1/ M.1/ Y.2	FOR FIELD REPLACEMENT TO REPAIR MODULE 58904	2000/ 4000/ 8000	X	
900022	B1/ M.1/ Y.1	CAPACITOR, 5MFD, (IGBT SWITCHING)	2000/ 4000/ 8000	X	
47556	B1/ M.1/ Y.1	CAPACITOR, 7.5MFD (MOTOR)	2000/ 4000/ 8000	X	X
CABLE ASSEMBLIES (CITIBUS)					
900225	B1/ M0/ Y0	CABLE, CITIBUS, 5'10"	2000/ 8000 NEMA 4	X	
900345	B1/ M0/ Y0	CABLE, CITIBUS, 6'3"	2000	X	
900626	B1/ M0/ Y0	CABLE, CITIBUS, 8'-9"	4000	X	
900627	B1/ M0/ Y0	CABLE, RS-232, 8'-9"	4000	X	
900343	B1/ M0/ Y0	CABLE, RS-232, 6'3"	2000	X	
900342	B1/ M0/ Y0	CABLE, RS-232, 5' 10"	060/ 200/ 1000	X	
901210	B1/ M0/ Y0	CABLE, CITIBUS, 10'	8000	X	
901211	B1/ M0/ Y0	CABLE, RS-232, 10'	8000	X	
900398	B1/ M0/ Y0	CABLE, CITIBUS, 6"	jumper cables--I/O module to other CITIBus devices	X	
CABLES (SIGNAL)					
908029	B1/ M0/ Y0	CABLE ASM CONVERTER 1 4n4 24P (DWG 908402)	4000 24P		
908030	B1/ M0/ Y0	CABLE ASM CONVERTER 2 4n4 24P (DWG 908402)	4000 24P		

PART NO.	QTY CODE	DESCRIPTION	VSC SERIES	Prior Model	
	BASE/MO/YR	*For calculating quantities, see instructions at end of list.*		Part Numbers	
				GCS	ICS
908031	B1/ M0/ Y0	CABLE ASM CONVERTER 3 4n4 24P (DWG 908402)	4000 24P		
908032	B1/ M0/ Y0	CABLE ASM CONVERTER 4 4n4 24P (DWG 908402)	4000 24P		
908035	B1/ M0/ Y0	CABLE ASM INVERTER 4 4n4 24P (DWG 908036)	4000 24P		
907781	B1/ M0/ Y0	CABLE ASM CONVERTER 1 8n4 12/ 24P (DWG 907780)	8000 12/ 24P		
907782	B1/ M0/ Y0	CABLE ASM CONVERTER 2 8n4 24P (DWG 907780)	8000 24P		
907783	B1/ M0/ Y0	CABLE ASM CONVERTER 3 8n4 24P (DWG 907780)	8000 24P		
907785	B1/ M0/ Y0	CABLE ASM CONVERTER 4 8n4 24P (DWG 907780)	8000 24P		
908401	B1/ M0/ Y0	CABLE ASM CONVERTER 2 8n4 12P (DWG 907780)	8000 12P		
908033	B1/ M0/ Y0	CABLE ASM INVERTER 1 8n4 12/24P (DWG 908036)	8000 12/24P		
908034	B1/ M0/ Y0	CABLE ASM INVERTER 2 8n4 12/24P (DWG 908036)	8000 12/24P		
TRANSFORMERS					
900024	B1/ M0/ Y0	CURRENT XFORMER 250:1	2060/ 2125		X
900549	B1/ M0/ Y0	CURRENT XFORMER 500:1	2200/ 2250/ 4300/ 4350		X
58946	B1/ M0/ Y0	CURRENT XFORMER 1000:1	4400 / 4500		X
901261	B1/ M0/ Y0	CURRENT XFORMER 2000:1	8000		X
907628	B1/ M0/ Y0	CURRENT XFORMER 2000:1 (LARGER HOLE FOR FPWM WITH NEW INDUCTOR)	8000		
902002	B1/ M.05/Y.05	XFMR CONTROL POWER 350 VA (OLD)	2000/ 4000		X
907953	B1/ M0/ Y0	XFMR CONTROL POWER 675 VA (NEW)	2000/ 4000/ 8000		
55533	B1/ M.05/Y.05	XFMR 240/480-120, 50/60 HZ	115V OPTION		X

PART NO.	QTY CODE	DESCRIPTION	VSC SERIES	Prior Model	
	BASE/MO/YR	*For calculating quantities, see instructions at end of list.*		Part Numbers	
				GCS	ICS
DISCONNECT SWITCHES					
905825	B1/ M0/ Y0	SWITCH, 150A	2060/ 2125/4300-4400 24P		
906659	B1/ M0/ Y0	SWITCH, 150A W/ TRIP COIL 24VAC	2060/ 2125 12P/ 4300-4400 24P N4 CE CONFIG		
905827	B1/ M0/ Y0	SWITCH, 250A	2125/ 2150-4300 12P/4400-4500 24P/8600-8700 24P		X
906649	B1/ M0/ Y0	SWITCH, 250A W/ TRIP COIL 24VAC	2125/ 2150-4300 12P/4400-4500/8600-8700 24P CE		X
906621	B1/ M0/ Y0	SWITCH, 400A	2150/ 2200/ 2250		
			4350 - 4500 12P/ 8600 12P8800-8900 24P		
906580	B1/ M0/ Y0	TRIPCOIL FOR 400A SWITCH	2150/ 2200/ 2250/8800-8900 24P CE CONFIG		
			4350 - 4500 12P 2 SWITCH CE CONFIG		
907404	B1/ M0/ Y0	SWITCH, 600A (LUGED ON LINE ONLY)	4300/ 4350		
906574	B1/ M0/ Y0	SWITCH, 600A (LUGED ON LINE & LOAD)	8600/ 8700		X
907405	B1/ M0/ Y0	SWITCH, 800A (LUGED ON LINE ONLY)	4400/ 4500		
906575	B1/ M0/ Y0	SWITCH, 800A (LUGED ON LINE & LOAD)	8800/ 8900		X
906580	B1/ M0/ Y0	TRIPCOIL FOR 600A SWITCH 24VAC	4300/ 4350/ 8600/ 8700		X
906579	B1/ M0/ Y0	TRIPCOIL FOR 800A SWITCH 24VAC	4300/ 4350/ 8600/ 8700		X
FANS/MOTORS					
903013	B1/ M.05/ Y.1	FAN MTR NEMA 4	2000/ 4000/ 8000		
47433	B1/ M.05/ Y.1	FAN BLADE 16" NEMA 3 & 4	2000/ 4000/ 8000	X	X
902488	B1/ M.05/ Y.1	GD FAN MNT SS WHT 2/4/8N4 GCS	2000/ 4000/ 8000	X	X
88424	B1/ M0/ Y0	FAN MUFFIN	2000/ 4000/ 8000		
902232	B1/ M0/ Y0	FAN HEAT EXCHANGER NEMA 4	2000/ 4000/ 8000		
FUSES					

PART NO.	QTY CODE	DESCRIPTION	VSC SERIES	Prior Model	
	BASE/MO/YR	*For calculating quantities, see instructions at end of list.*		Part Numbers	
				GCS	ICS
INPUT POWER					
900754	B3/ M.5/ Y2	FUSE, 50A	1060 12P/ 2060 12P/ 4050 - 4060 24P N1 & N4	X	X
85572	B3/ M.5/ Y2	FUSE, 100A	060 6P/ 1060 6P/ 2060 6P/ 1125 12P	X	X
			2075 12P/ 2100 12P/ 2125 12P		
			4075 - 4250 24P N1 & N4		
86804	B3/ M.5/ Y2	FUSE, 150A	2150 12P/ 2200 12P	X	X
			4300 - 4350 24P N1 & N4		
88895	B3/ M.5/ Y2	FUSE, 200A	1075 - 1125 6P/ 2075 6P/ 2100 6P/	X	X
			2125 6P/ 2250 12P		
			4400 - 4500 24P N1 & N4		
86805	B3/ M.5/ Y2	FUSE, 250A	200 6P/ 4300 12P/ 8600 24P N1 & N4	X	X
88896	B3/ M.5/ Y2	FUSE, 300A	2150 6P/ 2200 6P/ 4350 12P/ 8700 24P N1 & N4	X	X
900865	B3/ M.5/ Y2	FUSE, 350A	4400 12P/ 8800 24P N1 & N4	X	X
88897	B3/ M.5/ Y2	FUSE, 400A	2250 6P/ 4500 12P/ 8900 24P N1 & N4	X	X
88898	B3/ M.5/ Y2	FUSE, 500A	4300 6P/ 8600	X	X
86808	B3/ M.5/ Y2	FUSE, 600A	4350 6P/ 8700	X	X
88899	B3/ M.5/ Y2	FUSE, 700A	4400 6P/ 8800	X	X
86809	B3/ M.5/ Y2	FUSE, 800A	4500 6P/ 8900	X	X
SWITCHING SUPPLY PCB 906641 (OLD)					
907504	B2/ M.4/ Y1	FUSE 1A 600V TIME DELAY (F1,F2)	2000/ 4000		
54184	B2/ M.4/ Y1	FUSE 5A 600V TIME DELAY (F3, F4)	2000/ 4000		
901761	B2/ M.4/ Y1	FUSE,2A,250v,5x20MM,SLO-BLO (F5, F6)	2000/ 4000	X	

PART NO.	QTY CODE	DESCRIPTION	VSC SERIES	Prior Model	
	BASE/MO/YR	*For calculating quantities, see instructions at end of list.*		Part Numbers	
				GCS	ICS
907505	B2/ M.4/ Y1	FUSE,3.15A,250v,5x20MM,FAST ACTING (F7)	2000/ 4000		
SWITCHING SUPPLY PCB 908241 (NEW)					
53369	B2/ M.4/ Y1	FUSE 2A 600V TIME DELAY (F1,F2)	2000/ 4000/ 8000		
54184	B2/ M.4/ Y1	FUSE 5A 600V TIME DELAY (F3, F4)	2000/ 4000/ 8000		
901761	B2/ M.4/ Y1	FUSE,2A,250v,5x20MM,SLO-BLO (F5, F6)	2000/ 4000/ 8000	X	
908171	B2/ M.4/ Y1	FUSE 6.3A 250V 63 AIC FA GL 5MM X 20MM (F7)	2000/ 4000/ 8000		
HEATSINK COOLING FANS					
C85507	B2/ M.4/ Y1	FUSE, TIME DELAY, 10.0 A, 600 V	8000	X	
CONTROL POWER XFMR					
900967	B2/ M.4/ Y1	FUSE,2 AMP,250 VOLT,TIME DELAY (FU7)	2000/ 4000		
MOV					
902422 (PKG)	B1/ M.05/ Y.05	MOV PCB GCS NRTL NEMA 4	2000/ 4000/ 8000	X	
PLANAR BUS BARS					
901250	B1/ M0/ Y0	PLANAR BUS BAR, 2000 SERIES	2000/ 4050 - 4250 24P	X	
901271	B1/ M0/ Y0	PLANAR BUS BAR, 4000/8000 SERIES	4300 - 4500	X	
906701	B1/ M0/ Y0	PLANAR BUS BAR ASM 24P 4N4 / 8N4 ADV	4000 24P/ 8000		
HARDWARE					
900862	B2/ M0/ Y0	STDF, M-F, M8X1.25, M4X.7-6H, HEX	2125/ 2200/ 2250/ 4400/ 4500		
904719	B2/ M0/ Y0	SCREW PHHS M4 X 10MM SEMS CS ZINC PLTD	2000/ 4000		
OTHER					

PART NO.	QTY CODE	DESCRIPTION	VSC SERIES	Prior Model	
	BASE/MO/YR	*For calculating quantities, see instructions at end of list.*		Part Numbers	
				GCS	ICS
54162	B2/ M.1/ Y.4	BULB, LAMP, TYPE 120MB	OPTIONAL ON 2000/ 4000	X	
903248	B2/ M.1/ Y.4	MEMORY CARD, 128 MEG (CF card with adaptor)	OPTIONAL ON 2000/ 4000	X	
900717	B1/ M.05/Y.05	VCI-142 COMMUNICATIONS INTERFACE	OPTIONAL ON 2000/ 4000	X	
903194	B1/ M.05/Y.05	GCS EXPANSION I/O MODULE	OPTIONAL ON 2000/ 4000	X	
905857	B1/ M0/ Y0	USB FLASH DRV PMOD / DATA XFR ADV SERIES	2000/ 4000	X	
ADVANTAGE PWM FILTER RECOMMENDED SPARE PARTS LIST					
902059	B3/ M.1/ Y.1	CAP 40MFD +/-3% 480VDC .47-2M OHM	2000/ 4000/ 8000	X	
902049	B1/ M.01/Y.01	CNTCTR 75/94A 600V 3P	2000/ 4000/ 8000	X	
905838	B3/ M.01/Y.01	Auxiliary Contacts for 902049	2000/ 4000/ 8000	X	
900024	B1/ M.01/Y.01	XFMR CT 250:1 50-400HZ IT	2000/ 4000	X	
900549	B1/ M0/ Y0	CURRENT XFORMER 500:1	4000/ 8000	X	
86805	B1/ M.05/Y.05	FUSE 250A 500V FAST ACTING	4000	X	
88898	B3/ M.5/ Y2	FUSE, 500A	8000	X	
55535	B1/ M.05/Y.05	FUSE TIME DELAY 4.0 AMP 250V	2000/ 4000	X	
55533	B1/ M.01/Y.01	XFMR 0.275KVA 480/415/380-120 VAC	2000/ 4000	X	
55534	B1/ M.05/Y.05	FUSE TIME DELAY 3.0 AMP 600V	2000/ 4000	X	
902139	B1/ M.01/Y.01	INDCTR 80uH 600A RMS 4N4 GCS W/PWM FLTR (OLD)	4000	X	
907965	B1/ M.01/Y.01	INDCTR 80uH 600A RMS 4N4 GCS W/PWM FLTR (NEW)	4000 24P/ 8000		
86804	B1/ M.05/Y.05	FUSE 150A 500V FAST ACTING	2000	X	
902138	B1/ M.01/Y.01	INDCTR 160uH 300A RMS 2N4 GCS W/PWM FILTER	2000	X	
904860	B1/ M.05/Y.05	PCB, ANOLOG INPUT, LV, ADV, VSC	2000 / 4000/ 8000		

PART NO.	QTY CODE	DESCRIPTION	VSC SERIES	Prior Model	
	BASE/MO/YR	*For calculating quantities, see instructions at end of list.*		Part Numbers	
				GCS	ICS
ADVANTAGE ZERO CATEGORY STOP RECOMMENDED SPARE PARTS LIST					
	For the input switches with the under voltage trip coils see the DISCONNECT SWITCH section.				
900976	B2 / M0 / Y0	CLIP KIT FUSE 13/32 XFMR MTD	2000/ 4000	X	
900975	B2 / M.4 / Y1	FUSE 3A 250V TIME DELAY	2000/ 4000	X	
900974	B1 /M.05/Y.05	XFMR .05KVA 480/24 50/60HZ	2000/ 4000	X	
900973	B1/MO/ Y0	SW DISC FUSED 30A 600V 3P DIN MNTD	2000/ 4000	X	
900983	B2 / M.4 / Y1	FUSE 0.25A 600V 200KAIC 1.5"L	2000/ 4000	X	
903006	B1/M.05 /Y.05	RLY 24VAC 2PDT 11 PIN 10A	ALL 24P	X	
903007	B1/M.05/ Y.05	SKT RLY 11PIN 35MM DIN MNTG 300V 15A	ALL 24P	X	
900986	B1/M.05/Y.05	RLY 24VAC 4PDT 3AMP 14PIN	2000/ 4000/ 8000 6-12P	X	
49253	B1/M.05 /Y.05	SKT RLY 14PIN DIN MTG	2000/ 4000/ 8000 6-12P	X	

REMEMBER THAT THESE GUIDELINES ARE ONLY A STARTING POINT. AFTER HISTORICAL INFORMATION BECOMES AVAILABLE, THAT INFORMATION SHOULD BE USED TO CALCULATE REPLENISHMENT QUANTITIES.
The recommended quantity of spare parts for each of the part numbers listed above should be calculated using the quantity code and the VSC series listed for each part. The minimum quantity for each part is equal to the quantity after the B (Base) in the quantity code. For instance, the number B4 indicates that the minimum quantity for this part is 4. The quantity recommended for monthly resupply is the minimum quantity plus the number after the M in the quantity code times the total number of drives requiring this part.
The quantity recommended for yearly resupply is the minimum quantity plus the number after the Y in the quantity code times the total number of drives requiring this part.

Example:
20 Ea. 4500 series
15 Ea. 2250 series

For spare part number 900531, System control Board
Base quantity (B) =1
Monthly reorder level to maintain = 1+(.1X35) = 4.5 (round up - 5)
Yearly reorder level to maintain = 1+(.2X35) = 8

For spare part number 88897, 400A Fuse
Base quantity (B) =3
Monthly reorder level to maintain=3+(.5X15)=10.5 (round up- 11)
Yearly reorder level to maintain = 3+(2X15) = 33

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