Application Guidance Notes: Technical Information from Cummins Generator Technologies

AGN 124 – AVR Power Supplies

DESCRIPTION

The simplest way to provide a power supply for an AVR is to take power directly from the stator winding's output terminals. This system is very cost effective, offers design simplicity and so, good reliability and is the fundamental offering for small alternators in the STAMFORD range – types S0//S1, P0/P1, UC, S4 and S5 (HC5). Sharing the use of the alternator's output voltage between the connected load and the AVR can be troublesome, but 70% of the world's operating Generating Sets use this principle of operation. In Cummins Generator Technologies terminology, this type of alternator is known as Self-excited and these alternators are offered with an analogue AVR that is compatible, from the SX or AS range – SX460, AS440, AS540, AS480.

The provision of a dedicated power supply to an AVR will allow the alternator's excitation to be maintained and if required, forced, under situations where the alternator's output connections are being subjected to gross overload or may be a short circuit fault condition within the connected electrical network.

The ability to maintain and force the alternator's excitation system to levels that will force the alternator to provide an output current of several times rated current, whilst also maintaining an output voltage as close as possible to nominal, enables the alternator to provide good response to momentary overload conditions such as motor starting and under fault conditions – current levels that should activate the affected circuits overload protection Circuit Breaker or blow a fuse – and consequently continue to supply the remaining healthy circuits and connected equipment.

POWER SUPPLY SYSTEMS

There are several methods of providing a power supply to an AVR and most manufacturers of alternators will offer products with variations of the following methods:

Low Specification

Self-excited analogue AVRs, which are powered by the main output voltage, but are unable to sustain a steady state level of gross overload current. This is because if the alternator's connected load causes the output voltage – and so AVR supply – to fall below 60% of the nominal rated voltage, then the AVR becomes deprived of a stable power supply and consequently, is rendered incapable of providing any excitation and the alternator simply 'dies' until the overload condition is disconnected.

Medium Specification

A winding can be incorporated within the alternator's stator, which is designed specifically to provide an independent power supply for the digital or analogue AVR. By careful design and winding location this *"stator auxiliary winding"* is able to provide a stable output voltage to the AVR under all normal modes of operating conditions including up to some 150% of rated kVA. If the alternator is subjected to gross overload, or a virtual short circuit fault condition, then the "stator auxiliary" will increase the level of voltage available to the AVR and so, enable a high level of excitation forcing to develop in order to enable the alternator to respond positively to the overload condition.

High Specification

A small Permanent Magnet Generator (PMG) is mounted on the non-drive end of the alternator's shaft and the output of this unit is provided as an independent and totally isolated power supply to digital and magnet excited (MX) type AVRs. The PMG and the associated range of digital AVRs and MX type analogue AVRs have been designed to offer excellent performance under overload and fault conditions. They also offer outstanding performance when the alternator is connected to Non Linear Loads or expected to meet high performance expectation with regard to EMC specifications.

Rugged Specification

Compounding systems consisting of a transformer arrangement that combine to provide proportional increase in excitation by having the load's current flowing through the primary winding of the excitation systems transformer assembly, offer excellent performance under overload and fault conditions. This simple system has been used for many decades and is still considered to be the ideal solution for a rugged excitation system where operating under tight voltage +/- regulation % is not of paramount concern.

APPLICATION SPECIFICATION

Marine Classifying Societies stipulate the need for the alternator to be able to support a condition of sustained short circuit current. This identifies the above described stator-auxiliary-winding (Medium Specification) and the PMG system (High Specification) as being the two nominated systems for certified Marine applications.

Applications that specify low levels of Transient Voltage Dip [TVD%] under specified load step conditions enable the choice of the smallest possible alternator if the type of excitation system is carefully considered.

Technical loads consisting of a harmonically distorting Non Linear Loads can only be satisfactorily powered by ensuring the alternator is fitted with an excitation system that provides the AVR with an independent power supply. Here the PMG system is far superior to the Stator Auxiliary winding scheme. There are instances where the transformer control system is ideal.

Requirements of low levels of ‘noise’ associated with Electro-Magnetic Compatibility (EMC) require careful consideration with regard to the source of power supply to the AVR.

EXCITATION SYSTEMS

Low Specification, Self-excited analogue AS type AVRs are used on P0/P1, S4, and S5 (HC5) alternators, with a standard specification. AS type AVRs can also be offered on UC22 and UC27 alternators, as an optional specification.

The Medium Specification, AS540 type AVR powered by stator Auxiliary Winding, is available on S0/S1 alternators as a standard specification, identified as Winding 706. Many AvK alternators also use this medium specification design of excitation system with digital AVRs.

High Specification, PMGs are used in conjunction with digital AVRs as an optional specification on some STAMFORD and some AvK alternators – the design standard on S9 (P80) alternators. The PMG with MX type AVR is the standard design choice on S6 (HC6) and S7 (P7) alternators. In addition, the PMG is an optional specification with MX type AVR on UC22, UC27 and S4 alternators.

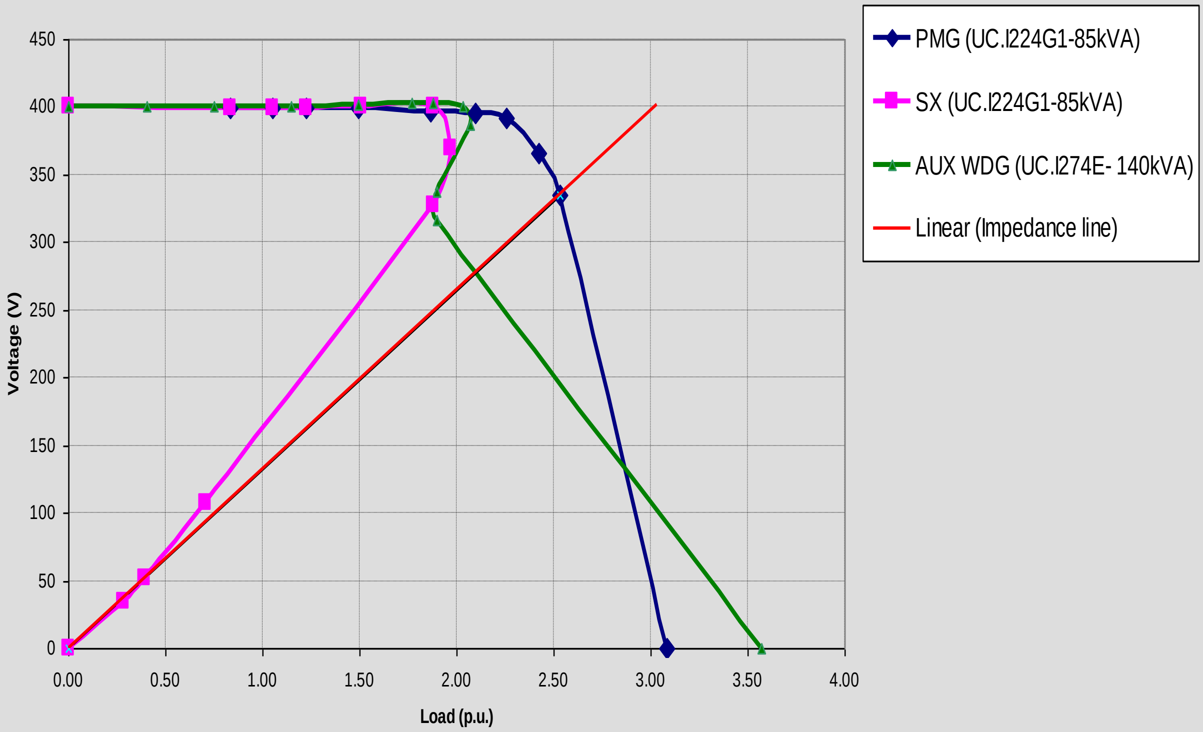
It is possible to retro-fit the PMG and MX type AVR with an ‘upgrade’ kit’ on UC22, UC27 and S4 special alternators.

A Rugged Specification Transformer Control system is offered on UC224 alternators. It cannot be retro-fitted to alternators originally manufactured for control by an AVR. This type of control system cannot be adjusted to change the operating voltage and so, at time of order the required operating voltage must be specified.

For further information on AVR compatibility with alternator types, refer to AGN024 – AVR Selection.

Overload Performance comparing the different types of Excitation Systems

The graph below is based on test data for an 85kVA alternator. The UCI224G alternator, which was fitted with an experimental stator auxiliary winding. The graph displays the comparative performance of the various types of systems used to power the AVR and so, the alternator's excitation level. The graph does not include a curve for the Transformer Control System, but this would show a curve that gently falls below and away from the nominal 400V line and passes through 350V at 2.5 pu load and 5.0 pu current under short-circuit, zero volts condition.



LOADING AVR VOLTAGE SENSING TRANSFORMER

From a position of good engineering custom and practice, the AVR voltage sensing transformer, typically used in machines above 480V, should never be used to supply a customer 'load' (burden circuit).

To ensure published and contractually binding functionality in terms of output voltage regulation performance of the alternator, the voltage sensing transformer installed on STAMFORD and AvK alternators is designed with an element of over capacity as a safety margin. On occasion, a customer may request authorization to connect a module associated with their Generating Set in terms of a 'burden' load to the sensing transformer, as a means to their cost saving, or as a space saving solution for their equipment package. This is more often the case for Medium Voltage (MV) and High Voltage (HV) alternators

The following reasons are provided as a technical explanation of why STAMFORD and AvK alternator voltage sensing transformers are not suitable for supplying 'burden' loads, identifying the pitfalls and consequences:

- Erodes an element of the transformer's capacity related safety margin.

- Introduces the risk that the current consuming characteristic of the customer's burden circuit could introduce an error with regard to the AVR's voltage sensing level, or may even have pulsating characteristic that, in turn, promotes the AVR to be unstable.

- The customer's connected cables may become damaged, or their burden circuit may develop a fault. Either situation will result in the AVR not receiving the correct level of sensing voltage with the risk that the alternator could become overexcited, where:

  - At best, an over voltage detector will take the alternator out of service.

  - At worst, some very expensive connected electrical equipment could be damaged.

Even after the above three points have been shared with a customer, their engineer's logic may challenge and reopen the debate that the transformer's designed VA rating is still comfortably above both the AVR's and the customer's proposed burden combined total loading level. To support the Cummins Generator Technologies policy, the following additional points must be considered:

- Good engineering risk mitigation insists their connected cables must include a carefully selected over-current device, which will disconnect all three phases should a fault develop - even if that is on only one phase. Thereby ensuring the AVR is still provided with an accurate and real time 3 phase sensing input.

- Finally the cable run will be selected to ensure;

  - There will be no electro-magnetic linkage with adjacent cables that may result in a harmonic distortion being imposed and generated within the voltage sensing scheme that may adversely affect the AVR's performance.

  - The cables are provided with a routing 'conduit', which provides sufficient mechanical protection to ensure they will not be accidentally mechanically damaged.

SELF-EXCITED EXCITATION SYSTEMS WITH NO AVR VOLTAGE OUTPUT

There have been occasional reports of Low Specification, Self-excited analogue AS type and SX type AVRs not giving an output voltage. This section provides a 'test procedure'. This test procedure must be conducted with NO LOAD connected to the alternator's output terminals. For procedural continuity, it is assumed the alternator is of a 4-pole rotor design:

1. Disconnect leads F1[X] and F2[XX] from the AVR and connect these exciter field leads to a 12V DC supply [battery or 2A variable voltage dc power pack] with F1[X] to positive.

2. Start and run, on no load, at the alternator's rated speed – 1500rpm for a 50Hz or 1800rpm for 60Hz.

The following voltages are quoted for an alternator fitted with the standard stator winding 311 or 312, connected in a series star (Winding 311) or star (Winding 312) connection and operating at 50Hz. A multiplying factor of 1.2 is to be applied for typical 60Hz voltages. If the alternator is fitted with a stator winding that is different from the standard Winding 311/312, or the standard winding is connected in a different configuration (Parallel Star or Series Delta), then apply an appropriate factor to the below advised voltage levels.

3. Measure the voltages at the alternator's output terminals between:
   - N- U
   - N- V
   - N- W

   All voltage readings should be the same voltage and the readings should be within 200V < 250V.

4. Measure the voltages at the alternator's output terminals between:
   - U - V
   - U - W
   - V - W

   All voltage readings should be the same voltage and the readings should be within 380V < 450 V.

5. Measure the voltage at the AVR sensing input terminals: 7 and 8. The voltage reading should be half the measured U-V voltage.

6. Stop the Generating Set. Disconnect the 12V DC power from the exciter F1 - F2 leads:

   - If all above tests provide balanced and expected voltage levels, then reconnect F1 and F2 exciter field leads to the AVR and re-start the engine. The alternator should self-excite and generate rated voltage. If alternator does not self-excite, measure the voltage across AVR input terminals. This should be over 5V.

   - If lower than 5V, then try 'flashing-up' the alternator as advised in the Owner's Manual (Installation, Servicing and Maintenance Manual). This involves running the Generating Set at rated speed, and then safely, but momentarily** apply 12V DC, with positive to F1[X], and negative F2 [XX] terminals of AVR, with the exciter field leads still connected.

     **momentarily means LESS THAN HALF A SECOND.

     Hopefully the alternator output voltage will build-up to the required level under the control of the AVR.

   - If the above tests produced balanced, and correct levels of voltages, and the voltage across AVR input terminals, once reconnected to AVR, is above 5V, but the alternator will not self-excite even after 'flashing', then a replacement AVR should be fitted.

7. If the above tests did provide balanced voltages, but not within advised levels, then there is a fault with the excitation system:

    - Check the overall appearance and then the resistance of the exciter field, which should be 20, +/- 5, Ohms.

    - Check the overall appearance and then the resistance of the main rotor winding, which should be about 2.0 Ohms.

    - Check the overall appearance and then the resistance of the exciter armature winding. This three phase winding is star connected, with two leads from each phase, with one of each pair going a +ve and –ve diode. The winding resistance values are very low and need to be measured with a four terminal bridge.

    - Check the conditions and appearance of the rotating diode assembly components. Testing diodes with a multi-meter on 'diode test' will not identify a diode that is faulty and breaking down under normal operating levels of applied ac voltage.

WARNING. WHEN CONDUCTING ANY BENCH TESTING ALWAYS WORK SAFELY, USING WELL MAINTAINED AND APPROPRIATE POWER SUPPLIES AND INSTRUMENTS, CONDUCTED IN SAFE WORKING CONDITIONS.

Remove the diodes and bench test on a 240V 1ph Mains supply, with each diode individually connected in series with a 40W < 150W filament bulb. A healthy diode will be identified when bulb is at half brilliance. A faulty diode is identified if there is no light or the lamp at full brilliance.

Inspect the rotating diode assembly surge suppressor. This device has a very high resistance and should show no signs of over heating.

If the above tests did not provide balanced voltages at the stator terminals, and the alternator made grumbling noises when being separately excited, then the stator winding is likely to be damaged.

Refer to the Owner's Manual (Installation, Servicing and Maintenance Manual) for winding resistance values and testing procedure.

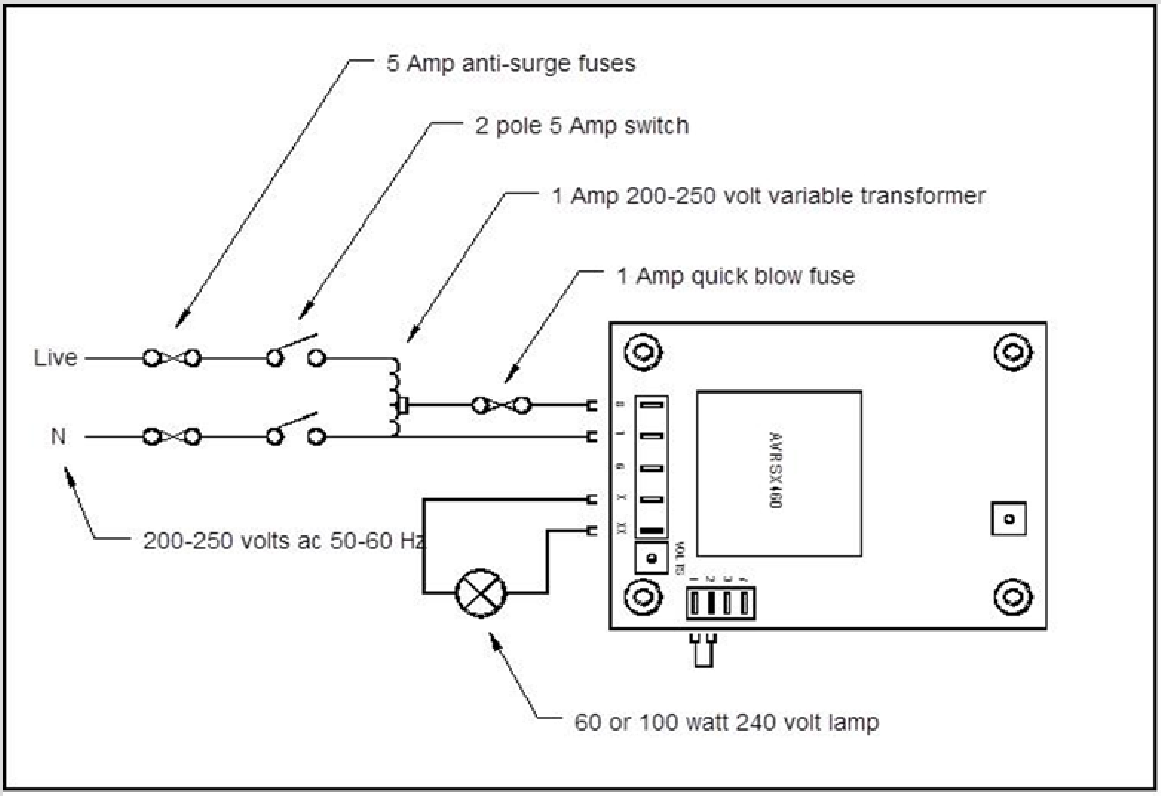
8. Re-assemble the alternator and repeat the above test procedure.

9. If all above checks are conducted and no obvious reason can be found for the alternator not to self-excite, contact your nearest Cummins Generator Technologies Customer Support Team, through the website www.stamford-avk.com.

BENCH TESTING FOR SELF-EXCITED TYPE AVRs

This following 'Bench Test' procedure was produced specifically for SX460 type AVRs, but may be adopted for all other SX and AS type AVRs.

The diagram on the next page is in reference with the SX460 type AVR.



WARNING. ALL CONNECTIONS MUST BE MADE AND DISCONNECTED WITH THE MAINS SUPPLY ISOLATED.

To test the AVR:

1. Switch off the mains supply and connect the AVR as shown in the diagram above.
2. Turn the AVR Volts potentiometer fully anti-clockwise.
3. Turn the variable transformer to the minimum volts position.
4. Switch on the power and adjust the variable transformer so that 6 volts ac is present across terminals 7 and 8.
5. Measure the voltage across terminals x (+) and xx (-). This should be greater than 1 volt dc.
6. Slowly adjust the variable transformer so that 100 volts ac is present across terminals 7 and 8.
7. Ensure the lamp is now be glowing.
8. Slowly adjust the variable transformer such that that 200 volts ac is present across terminals 7 and 8.
9. Ensure the lamp is now not lit.
10. Adjust the variable transformer to the minimum voltage position.
11. Switch off the mains supply and disconnect the AVR. Test complete.