Application Guidance Notes: Technical Information from Cummins Generator Technologies

AGN 037 – Terminal Arrangements

INTRODUCTION

The terminal box components within STAMFORD and AvK alternators include a variety of copper bars, which interconnect the stator winding electrical terminals. Each copper bar has been duly designed to meet engineering requirements for the prevailing operating levels with regard to current density and running temperatures, when considered against their designed location and functionality.

The conductors connected to the output terminals of an alternator must be carefully selected, ideally with a cable supplier's approval and compliant to International Standards for a Generating Set design that will offer resistance to heat and movement flexibility.

Resistance to Heat

We remind Generating Set manufacturers of the heat that will be generated within the alternator's windings. Temperatures approaching 150degC are expected and this heat will be conducted into the alternator's output terminals.

Movement Flexibility

The electro-mechanical assembly of a Generating Set is not a stationary assembly. Movement takes place in all three planes. It vibrates when running and goes through quite considerable oscillatory movements during starting and stopping. AGN008 offers information on the vibration levels and shock load capabilities of the alternator.

This AGN provides information on the alternator's terminal arrangement, with specific guidance to the Generating Set manufacturer on the selection of output cables and conductors.

TERMINAL BOX AND TERMINAL ASSEMBLY

Note of clarification. The design of switchgear chamber Bus-Bars are controlled by engineering standards applicable to that application. Consequently, engineered control of the operating levels of current density, volt-drop considerations along with mechanical integrity under fault conditions combine and so result in stipulated levels of current density and Bus Bar chamber constructional designs.

Such engineering standards should not be applied to alternator, motor, or transformer copper bars located within the confines of their equipment structure inherent terminal arrangement.

Terminal Assembly

STAMFORD and AvK alternators are offered with an output termination arrangement of a construction that is considered to have - based on experience - sufficient surface area and appropriately sized holes for a bolted termination of each output conductor's connection-lug. This connection will have a high contact surface area and provision for the conductor to be clamped directly to the provided alternator terminal area.

The conductors must be mechanically supported as they enter the metal work of the terminal box, using an appropriate form of glanding. This glanding will help support the weight of the conductor and so will not subject the alternator terminal assembly to high levels of bending moment, which will be amplified by the vibratory movement of the whole alternator assembly in normal service. Problems can arise from additional mechanical loading associated with unsupported conductors, and poorly fitted Current Transformers which add to the already present electro-mechanical stress levels within the terminal structure.

The terminal assembly, and copper bars used as component of the terminal assembly, have been designed, verified and validated with all due consideration to current density and operating temperature. The tinned copper bars conform to BS 1432, copper grade C101, and they are supplied with 'hard conditioning' (H). The plating quality and performance comply with BS EN 1456.

Consideration of voltage drop related to the terminal assembly and copper bars current density is virtually irrelevant within the confines of an alternator's terminal box, because the copper bars are so short in length.

Temperature

The copper bars in the terminal assembly are directly connected to the stator leads. The assembly will operate at levels of current density that will elevate the copper bar operating temperatures. The temperature will vary accordingly with the stator winding thermal conditions, which are related to the alternator's operational output rating (KVA).

Consideration of copper bar operating temperature must include due consideration of the conducted heat from the stator windings, and therefore, is not simply related to, or controlled by current density levels.

Consideration of the operating temperatures of the supporting terminal assembly does take into account conducted heat from the stator leads, with the terminal box ambient temperature being controlled by due design of terminal box ventilation scheme and air movement provided by the alternator's cooling fan.

Vibration

With the output terminal assembly (and terminal box) being part of the frame construction of each design of alternator, this whole terminal area will move in sympathy with the complete engine-alternator assembly. Movement will generally be in line with the imposed vibration characteristics created by the engine, which in turn is then conducted throughout the unique design of the Generating Set assembly.

With the alternator's terminal assembly being at a radial distance/offset from the Generating Set shaft centre line, the actual level of operational vibration in the terminal region will certainly be modified and amplified to any measured vibration levels identified by the ISO8528-9 method. Consequently, the actual level and characteristic of terminal assembly and terminal box movement, resulting from imposed vibration, will need to be identified for each Generating Set manufacturer's unique design.

ELECTRICAL OUTPUT CABLES AND CONDUCTORS

Good engineering practice for Generating Sets requires consideration of the electrical requirements for the chosen conductors destined to be connected to the alternator's output terminals and then over what distance will these 'un-protected' conductors travel. Particularly, Generating Set manufacturers and installers must carefully consider the engineering and environmental requirements for:

- The type of output cabling/conductor. Experience has shown that poorly chosen output cables from a Generating Set will fail. Therefore using standard PVC type cables, of single core or multicore, which are manufactured with few, large diameter, conductor strands and therefore are not flexible or designed for temperatures above even 100degC, will NOT be suitable.

- The need to apply the correct torque settings for connecting the output cabling/conductors. Torque settings vary, depending on alternator type and size and the required settings should be provided with the alternator. For example: for UCI224 and UCI274 alternators, the torque settings is 20 – 30 Nm, for S4, S5, S6 and S7 alternators, the torque settings is 40 – 50 Nm.

- The associated glanding/bushings required for the cables/conductors required at the alternator's terminal box side.

- The need to provide physical support for the cables/conductors as they leave the vibrating mass of the engine and alternator, before they become clamped to a rigid and fixed structure.

- The need to terminate at a junction box fixed to a non-moving, rigid and fixed part of the Generating Set base assembly or to the floor space adjacent to the Generating Set.

- The junction box is often used to house the Generating Set Circuit Breaker. From this junction box the Generating Set's output needs to be conducted through appropriate cables, which again must be chosen for compliance with the conditions and environment.

- If the Generating Set Circuit Breaker is mounted within a junction box structure attached to the Generating Set's frame/body, then it can be expected that both the cables and terminals will have virtually zero relative movement, therefore offering the opportunity to use either solid bus-bars or a lamnicon type conductor

- Here there is the need to consider Electro Magnetic Radiation from the cables. This will dictate the suitability of single core, or multicore cables, and the chosen method to achieve a Trefoil twist to neutralise radiated flux.

- If the Generating Set is to be connected to a nearby floor standing electrical cubicle, incorporating the Generating Set Circuit Breaker, then there is the obvious need to connect the moving/vibrating alternator terminals to a very flexible conductor, which will then exit the alternator's terminal box via suitably engineered glanding arrangement. This conductor will then travel to a floor mounted junction cubicle located adjacent to the Generating Set base frame. From this junction cubicle, the required type of marine specification cable can then be used to travel to the local electrical control panel incorporating the master Circuit Breaker and appropriate Generating Set output monitoring package.

- If the Generating Set is to be connected to a long run of cable, which is to be supported by cable tray, therefore, solidly fixed to walls /ceiling/ floor adjacent to the Generating Set and so, not moving in sympathy with the engine-alternator assembly, then great care must be taken with the choice of:

    - The cables specification, particularly attention to ensuring flexibility.

    - The cable's support and routing, between the floor/wall/ceiling mounted fixed cable tray and Generating Set moving/vibrating terminal box.

    - The cables entry to the terminal box and here, cable glanding and side of terminal box's inherent strength/weakness need to be considered.

    - Required modification to the terminal box cable entry region to carry the unsupported mass of a vibration absorbing 'swan-neck' that has been

engineered into the cable between the clamped and fixed section of cable and the moving glanded part of the cable at the terminal box side.

REVERSE TERMINAL ARRANGEMENT

It is possible for the customer to request a reverse terminal arrangement on many STAMFORD and AvK alternators. This effectively offers the Generating Set manufacturer an alternator terminal assembly that is the mirror image of his standard arrangement and provides for cable entry from the opposite side of the alternator.

For changing the cable entry on an HC5 (S5), S6 and P7 (S7) STAMFORD alternator after manufacturer, when ideally the Generating Set manufacturer would like his cable entry to be the mirror image of his standard arrangement – N W V U looking from the NDE – there is a design flaw. This is not possible, as the 'U' and 'W' stator cables cannot be switched over. The Generating Set manufacturer must therefore bring his cables into the terminal box in the configuration – N U V W. This decision must be made before he makes his cables entry. The Generating Set manufacturer should use the following procedure:

- Disconnect all main stator terminals and rotate the main terminal rail assembly. The Neutral terminal is now at the opposite end of the terminal box (non-drive end), so all phase terminals are shifted towards the drive end.
    - NOTE: This means that the stator cables must also be shifted towards the drive end, so far, we have managed to do this on all STAMFORD frames sizes from HC5 (S5) to P7 (S7) (6 ends out windings on S6 and P7 (S7) are more difficult).
- Remove the 'U' and 'W' phase markers on the terminal rail, and switch them over, ('U' phase becomes 'W' phase, and vice versa). All Neutral cables (the 2's) now become the phases, and all phases (the 1's) become the Neutral.
    - NOTE: It's easier to modify markings on the customer wiring diagram than alter the cable markers).
- Carefully removed cable ties and re-position the cables, to reach the new terminal positions.
- Move the DROOP C/T from W2 across to W1 cable (S1 - S2 remains as before).
- Cable tie all stator leads tightly together, making sure that all adjacent leads are tied, and are also tied with any touching cables. (This is essential to avoid cable sleeving fretting with vibration).