Application Guidance Notes: Technical Information from Cummins Generator Technologies

AGN 186 - Rail Applications

OVERVIEW

Nominating and applying AvK and STAMFORD alternators to Rail Applications needs to be given very careful consideration. There are many challenging aspects for the alternator and the following list of items is provided as a check list for basic fundamental technical considerations. At the initial stage of rail application discussions with the prospective customer, it is imperative that an understanding of their experience in this specialist field is understood. The life expectancy of the AvK or STAMFORD alternator will be totally dependent upon their ability to control and protect the alternator from imposed challenging conditions.

A special STAMFORD alternator has been developed over the last 20 years for rail applications, but this product is only available as a derivative of the HC5 model. There are many applications where other STAMFORD frame types have been deployed. Alternatively, an AvK alternator may be considered for its suitability for rail applications. Ultimately, the suitability of an alternator for a rail application is totally dependent upon the experience of the Generating Set manufacturer, in designing a suitable product and his contractual control over installation and in-service maintenance.

It is important to engage Application Engineering at the earliest opportunity. Contact applications@cummins.com.

TECHNICAL CONSIDERATIONS

The alternator must be regarded as a component part of the entire electrical system. And that electrical system must be designed specifically for the installation on the rail carriage and the

individual application of the alternator/Generating Set. Application Engineering would need to know specific details of the application, to ensure the alternator is suitable for the load demands and environmental conditions. A questionnaire check list has been developed to capture this information. The check list includes the following aspects.

Characteristics of the electrical load

Top level: We need to know the use - traction motors or passenger carriages?

Tech level 1: What is the alternator operating speed, voltage, kVA, kW, power factor?

Tech level 2: What is the duty cycle based on a typical operating mode, ideally developed as a load diagram.

Tech level 3: What are the current consuming characteristics in terms of harmonics, transient overload, temporary peak loads, steady state loads; all qualified in kVA and power factor.

Location for the Generating Set

What levels and technology will be provided for environmental protection and so proposed location for the alternator?

What are the proposed operating ambient conditions in terms of temperatures, altitude, humidity, air borne contaminants.

Alternator bearings

Will the installation require a single bearing or two bearing alternator?

SAE scheme

Will the installation require an engine Adaptor and flywheel flexible Coupling? Provide SAE numbers.

Frame construction

What is the required terminal box and output cable configuration?

Output connections

Provide information on output cable length flexibility. Also, Exciter field leads and PMG lead lengths, as appropriate.

AVR location

State the interconnection suitability to the alternator-based components.

Running speed

Will the alternator be operating at fixed speed or variable speed?

What is the proposed range of speed variation and what is the rate of change? Some indication of duty cycle at each node is also required.

What is the rate of acceleration between speeds, to enable consideration of the alternator fan casting integrity?

What is the associated voltage range at the various speeds?

For further information on variable speed operation, refer to AGN 041.

Imposed Vibration levels

What are the X Y Z axis values?

Imposed Shock loads

What are the severity and duration of forces, as vehicle travels along 'rough' rail-tracks and during the coupling and uncoupling of wagons?

Brinelling

What would be the imposed vibrations suffered by the non-running Generating Set? There must be a plan to rotate the 'stand-by' unit at regular intervals to ensure the alternator's bearings are kept 'lubricated'.

For further information on vibration and shock loads, refer to AGN 008.

Loading levels

If hotel load, then provide an understanding of the operating scheme that will be imposed on the Generating Set to ensure the passenger carriages are at temperature, etc. to satisfy the rail operator's need to provide passenger comfort.

If traction, then provide information on the proposed control over the driver's ability to 'force' tractive effort and resulting transient/peak loading levels. If it is a variable speed Generating Set, then how will the control function for engine speed interact with demand for electrical power set by the operator/driver?

This will give some guidance regarding loading levels at given running speeds and so will allow theoretical thermal conditions to be identified.

Duty cycle

Provide information on duty cycle; to gain an understanding of in-service operating temperatures, the proposed loading levels must be established and these considered against the environmental operating conditions.

Harmonic analysis

It is important to identify the likelihood of imposed dielectric stress to the alternator's insulation system. Provide details of any electrical loads that have a harmonically distorted current waveform that will force a distortion to the alternator's voltage waveform and by so doing, will impose stress on the insulation system. Gathered data identifying such conditions will enable the dielectric stress of the insulation system to be identified.

Running thermal conditions

Establish who will be responsible for airflow management strategy and provide a copy of their engineering validation data. It is important to check; to ensure the alternator will not suffer from inadequate cooling as well as taking into account the extra heating from high harmonic content of certain loads.

Locomotive variants into which the Generating Set will be incorporated

Provide an understanding of the variations of locomotive or passenger carriages into which the Generating Set may be incorporated.

ALTERNATOR NOMINATION

Once the above aspects have been discussed and considered, the robustness of the required alternator will become apparent and the desired strengths identified. From here, such aspects as the required level of electrical power quality, through to special mechanical considerations will combine to allow a first pass nomination of an appropriate AvK or STAMFORD alternator product can be made.

It is most unlikely, a standard industrial alternator will prove to be satisfactory without the benefit of a knowledgeable and experienced Generating Set manufacturer taking great care to ensure the operating environment has been fully understood and the challenges controlled by engineering solutions.

Often Generating Sets are installed on the locomotive with no engineered protection against water and dirt ingress. Consequently, rain water and air borne contamination is able to gain easy access to windings and subsequent failures occur. Mixed responsibilities and poor control between the Generating Set builder and the installation company can lead to premature failures, disappointed locomotive operators and challenges in getting the appropriate party to accept responsibility, make modifications and accept blame.

There follows a typical Rail Application Specification. This specification has information that may provide a better understanding of the depth of consideration required for these applications.

STAMFORD alternator design for a typical Rail traction specification

The STAMFORD HCI504E1 alternator has been manufactured to a typical Rail specification. A comparison between a standard industrial alternator and an alternator designed for a typical Rail specification is detailed in Appendix A on Page 7 of this AGN. Firstly, this section looks at the design requirements required to meet a typical Rail specification.

Construction

The stator winding shall be fitted with 6 x PT100 type RTD's (2 per phase). The unit shall be fitted with a non-standard fan, suitable for operation at 1900rpm. The alternator shall be fitted with an SAE 1 stiff adaptor to suit a Deutz, V8; 2015, Tier 3 engine. The SAE coupling disc shall be SAE14. Enclosure covers to IP23 industrial. A general arrangement for the alternator is shown in Drawing No. A048S383.

Operation

The alternator shall operate over a speed range of 1400rpm to 1900rpm. Figure 1 indicates the maximum power at 600V, 0.95pf that can be drawn under continuous operating conditions.

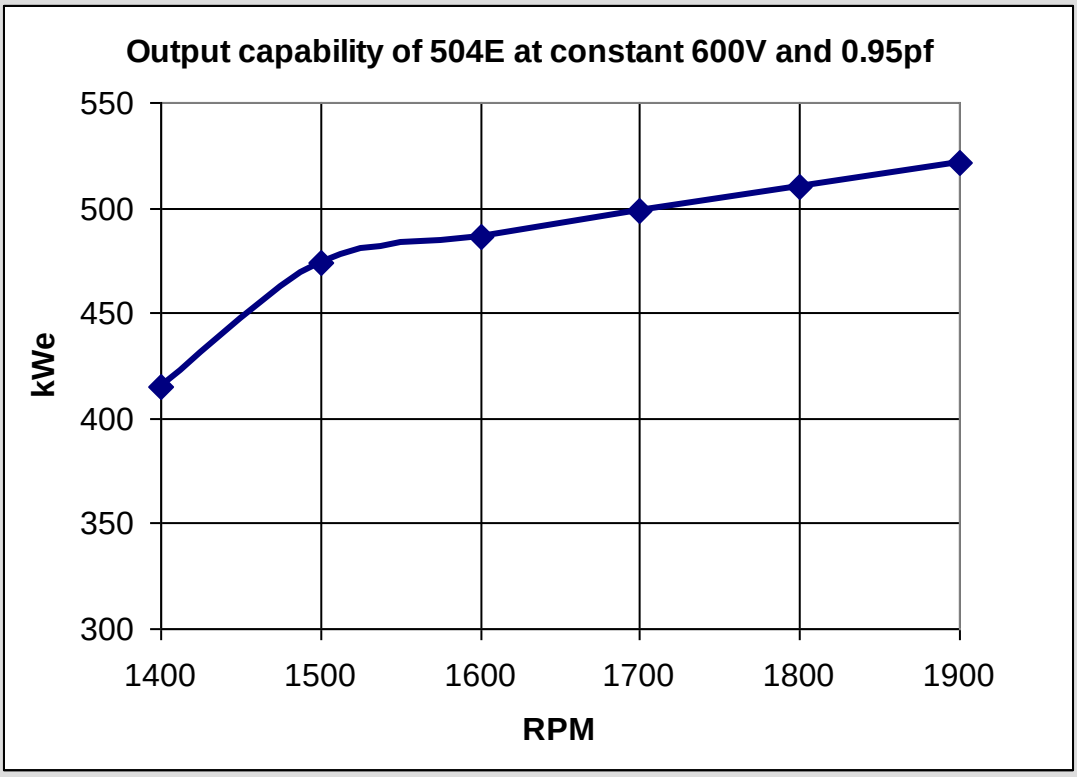

Figure 1 shows maximum continuous power at 0.95 pf, 600V

The thermal performance of the alternator over the speed range 1400rpm to 1900rpm is 105/50ºC under a balanced, non-distorting, linear load.

The final operating temperature and impact of a distorted voltage waveform, due to non-linear harmonic distortion as a result of applied load, shall be the responsibility of the Generating Set manufacturer.

Environmental

Cooling air inlet temperature shall not exceed 50ºC and restricted air flows are not acceptable if they result in the cooling air temperature rise across the alternator exceeding 35ºC, while operating in accordance with Figure 1.

Excitation

The machine shall be supplied with no AVR and it is the responsibility of the Generating Set manufacturer to ensure the alternator is adequately protected and not taken outside the agreed operating conditions specified in this document.

Maximum alternator vibration levels during steady state operation

Vibration levels are a major consideration for the alternator's suitability:

- The stated vibration levels are broadband figures measured across the frequency range 2Hz to 1000Hz.
- They apply to all operational planes (e.g. X, Y and Z).

Engine Speed (rpm)	Vibration displacement (S rms) [mm]	Vibration Velocity (V rms) [mm/s]	Vibration Acceleration (A rms) [m/s²]
> 720 & < 1300	0.35	22	14 (1.4G)
> 1300 & < 2000	0.45	28	18 (1.8G)

Shock loading

The alternator is likely to see shock loading during its life, due to the nature of the application and operating environment. With respect to peak loads, the following criteria must be applied:

- 5.0 G peak < 5 cycles / life of the machine.
- 3.0 G peak < 10,000 cycles / life of the machine.

Non running sets

The bearings on stationary alternators may be subjected to external vibration sources and can suffer a failure mechanism termed 'false Brinelling'. Effectively, the moving elements of the bearing are forced to oscillate backwards and forwards removing the protective oil film between them and the outer and inner raceways. If not prevented, the resulting wear mechanism will significantly reduce the life of the bearing.

It is the responsibility of the Generating Set manufacturer to ensure all reasonable precautions are taken to prevent the occurrence of false brinelling. To minimise the effect, the following actions are recommended to ensure:

- The set isolation system is designed correctly to minimise the transmissibility of external vibration sources into the stationary structure.
- The non-running sets are turned over at least once an hour to renew the raceway grease / oil films.
- Where more than one unit is fitted per locomotive, the utilisation of the Generating Sets is rotated to ensure that all clock up equal hours.
- Condition monitoring techniques and devices are used to monitor the bearing's wear at agreed intervals. (Suggested time frame = 3000 hrs).

Alternator maintenance

The bearings on STAMFORD alternators used in Rail applications should be changed every 15,000 hours, or during major engine overhauls; whichever occurs soonest.

Appendix A

This Appendix offers a comparison between a standard STAMFORD industrial alternator and a STAMFORD alternator that is designed for a typical Rail specification.

Stator winding

The electro-magnetic design must take into account the variable speed requirement, whilst generating a constant voltage output (600Vrms is typical). The harmonic distortion generated by the non-linear current consuming characteristics of the connected traction motor drive system, require the insulation system to incorporate enhanced dielectric strength and this is achieved by the incorporation of extra phase to phase separation and coil out-hang over taping.

The stator winding is internally connected into STAR (wye) with output connections being provided by internally connected flexible leads (2 per phase + N cable of some 25mm²).

For reference, the standard industrial alternator does not have its out-hangs taped. The out-hang is treated to the standard VPI process but is terminated at a frame mounted bus-bar arrangement.

Rotor assembly

The imposed shock loads require extra security of the rotor core pack assembly. This is achieved by grinding the shaft diameter to a specially controlled tolerance (compared to the standard industrial alternator) and the rotor core pack is located by the use of special collars, which are then shrink-fitted onto the shaft to stop an axial movement of the rotor core assembly (no such collars are required for the standard industrial alternator).

Rotating Diode Assembly

The positive and negative heat sink plates are of an increased material thickness, necessitating a special assembly of this unit. The change to the plates is to counter imposed torsional and dynamic stresses associated with variable speed operation and rail-track motion.

Shaft mounted Cooling Fan

The cast aluminium cooling fan is based on a ‘stronger’ design to take into account the variable speed element of operation and the imposed torsional and dynamic stresses associated with rail-track motion.

Stator frame

The frame is specially constructed to provide a gland plate, through which the output flexible cables are ‘gripped’ and identified.

Frame to Flywheel-housing Adaptor

The Tier 3 compliant Deutz engine requires a special adaptor, which needs to be stiffer than a standard product and also to have special modifications to clear the engines (re-located) Turbo-charger.