Cummins Generator Technologies

Application Guidance Notes: Technical Information from Cummins Generator Technologies

AGN 032 – Motor Starting Methods

INTRODUCTION

The information included in this Application Guidance Note should be used in conjunction with AGN090 – Motor Starting Fundamentals and AGN068 – Motor Starting and Generating Set Considerations.

FREQUENCY START OR EXCITATION START OF MOTORS

Both the Frequency Start and the Excitation Start methods of motor starting enable a Generating Set to start a larger induction motor than would normally be possible with the available Generating Set, because of the typically high levels of inrush (Locked Rotor) current associated with a normal starting procedure for this size of motor.

However, both are dependent on the motor not having to accelerate to speed a coupled load that has a high torque requirement. Both systems have their own subtle merits, making it difficult to offer exact guidance regarding which would be best for certain individual applications.

Test results are not readily available as most experience is gained on site during the commissioning of the Generating Set and the gathered test data is never passed back for analysis. In house experience recalls that, during tests conducted some years ago, on a small [50kVA] Generating Set, either start method would successfully start larger motors with an inrush current in the order of some 2 x rated current of the motor.

The benefits between each scheme being more related to the rate at which the engine accelerates from standstill to rated speed.

If this acceleration is quite slow, then FREQUENCY START should result in the lowest level of inrush current because, for a short period, the 'slip frequency' is less [but it is only for a very short period of time].

If this acceleration is quite rapid, then it may well make more sense to allow the engine to run at rated speed for a short period to allow it to stabilize, and then switch on the alternator's excitation. This is EXCITATION START. This may well result in the engine speed dipping, due to load, as the alternator excites and forces current through the motor, which in fact, will result in a reduced slip frequency, combined with reduced voltage across the motor terminals, so reduced inrush current.

Alternators for Starting Large Induction Motors

In all cases where large motors are required to be started, alternator size is governed by either voltage dip or maximum overload forcing capability of the excitation system (generally 2.5 times the normal running current level).

Certain applications allow a different approach to the starting of large motors, e.g. a large pump supplied by a Generating Set, which supplies only a small proportion of additional load such as in the case of a fire pump on board ship. This type of application enables consideration of 'frequency start' or 'excitation control', in order to minimize the alternator size required.

FREQUENCY START OF MOTORS

This refers to the situation where the motor is permanently connected to the alternator and the complete system is started simultaneously with the engine. This demands a separately-excited excitation system, with PMG or Auxiliary Winding, where voltage build up is positive and high forcing is available at relatively low speeds. In principle, the PMG control system has a voltage output characteristic that varies linearly with speed, or frequency, which means that the driven induction motor can produce a high torque level during the run-up period without excessive current. The current level reached during starting will be dependent upon induction motor drive inertia, the difference between motor and driven load torque speed characteristics, engine run-up time, and excitation build-up time.

Testing carried out on STAMFORD separately excited alternators have shown that a motor size equivalent to 1 h.p. per alternator kVA can be started against no-load with a maximum current drain of approximately 2 x normal full load, using an alternator set run-up time in the region of 2 seconds. In fact, larger motors could be started, but not run, on full load.

EXCITATION START OF MOTORS

Main engine driven alternators on board ship may be in a situation that is suitable for frequency starting but it is not possible to employ this method, because of the undesirable element of stopping the main engine. In this instance, it is possible to employ a slightly different technique, which involves switching the alternator excitation. Here again, the induction motor is permanently connected to the alternator terminals, but in this case the engine is run-up with the alternator de-excited. When the engine reaches speed the induction motor may be started by switching in excitation to the alternator. Voltage build-up against load is a necessary feature of the excitation system and alternators with PMG or Auxiliary Winding systems meets this requirement. Current levels during the starting period of a 20 h.p. motor on 15kVA alternator in development experiments were approximately 3 x (as compared with 2 x in Frequency start).

This system depends on the induction motor being able to produce sufficient torque to accelerate the drive at low voltages at the full frequencies. It is, in effect, equivalent to an auto transformer start with infinitely variable tapping, varying over the range 0 - full volts. Even for low torque applications it will be necessary to reach 20-25% of full voltage before the induction motor begins to accelerate.

Because the frequency of the alternator output is always at full value, regardless of output voltage level, starting against load will demand larger currents than the frequency start method. Both the above systems can only be applied satisfactorily to PMG or Auxiliary Winding controlled alternators and are really only suited to those applications that involve relatively low starting torque and low inertia drives as the induction motor load. As pointed out above, consideration must be given to engine torque / speed characteristic during run-up as ultimately the torque required by the final drive has to be supplied by the engine.

This Excitation Controlled method of motor starting may also be used for applications such as driving pumps that are installed in the vertical axis. This system requires an initial torque ‘kick’ to overcome ‘stiction’ of the pump motor bearings and then the next demand for kW will be the point the impeller develops a positive head pressure and initiates flow.

The pump motor will be directly connected to the Generating Set and the start procedure will be to excite the alternator with a controlled ‘excitation-build-up’, which will provide a soft approach to voltage build-up of the alternator and so in turn, the motor’s demand for torque as the motor successfully accelerates the pump impeller to rated speed.

It does require the alternator to be fitted with an excitation system that can support a steady state short circuit current - this means the separately excited (Series 3) excitation system of PMG + MX type AVR must be nominated, or an equally suitable excitation system with auxiliary winding.

Method

1. Ensure the alternator excitation is switched off. On an MX type AVR, terminals K1 and K2 must be open circuit. A 240V ac 10A single pole switch may be used for this purpose.
2. Connect the stationary Generating Set to the pump motor.
3. Start the engine and allow the Generating Set to run up to speed.
4. When the Generating Set is at full speed, switch on the alternator’s excitation.

The AVR will now excite the alternator and as the excitation builds, the Generating Set output current will also increase, which will accelerate the pump impeller to rated speed. Within a matter of seconds the Generating Set output voltage will reach the rated voltage and the system load will consist of the motor's running current demand.

Example

It is easier to use an example to explain the Excitation Start method:

A Generating Set supplying 400V 50Hz. The Shaft power required is 420kW and the operating speed is 586rpm. The proposed engine power is 572kWm.

The assumed motor efficiency is a typical value of 94% and the assumed motor running power factor is 0.8 lagging. The assumed motor is a Direct-On-Line (DOL) type with a starting factor of 6 x running kVA.

Calculation for motor run kVA = 420kW / [motor efficiency 0.94 x running pf 0.8] = 560kVA.

We must now make many assumptions regarding the motors demand for torque, as the motor successfully accelerates the pump impeller to rated speed. Based on experience, most pumps can be started by a Star/Delta method, or indeed an Auto-Transformer method with tap setting of some 50%. Either of these methods will result in the actual start current being some 2.5 times the normal running current level.

The predicted Locked Rotor start kVA for a typical DOL start if 100% rated voltage is applied is 6 x 560 = 3360kVA.

The motor peak level of stator winding current for this DOL starting is 3360 / [voltage 0.4 x 1.732] = 4850A.

The predicted Locked Rotor start kVA for typical Star/Delta or Auto-Transformer at 50% tap setting is 2.5 x 560 = 1400kVA.

The motor peak level of stator winding current for this Star/Delta or Auto-Transformer starting is 1400 / [voltage 0.4 x 1.732] = 2020A.

The predicted peak level of demand for kWm from the pump, assuming the electric motor has been sized correctly, can be identified by assuming the motors Locked Rotor starting power factor is in the order of 0.15.

For the DOL start, this calculates to 3360kVA x 0.15 = 504kW.

This very simple calculation (it has to be simple because there are so many unknowns associated with pump performance characteristics) does align with the identified: Proposed engine power = 572kWm.

Summary of starting method:

Based on the above indicated values, in conjunction with rotating electrical machine performance experience, the pump motor will successfully start if the Star/Delta level of motor start current is forced through the motors windings.
Following this route identifies that the key factor is to align the above identified Star/Delta or Auto-Transformer motor start current level with the sustained short circuit current displayed on the nominated alternator's Sort Circuit Decrement Curve. However, the Decrement Curve indicated level of sustained fault current is based on a fault condition of virtually Zero Impedance and the situation with forcing current through the motors winding will impede current flow and so, a factor of some 0.85 should be applied to the indicated Decrement Curve level of sustained three phase fault current level.

Nominating an alternator for the 420kW motor, details of which are covered in the above calculations:

The identified Star/Delta or Auto-Transformer starting current level is 2020A.

The nominated alternator must have a sustained three phase short circuit current of more than 2020 / 0.85 = 2375A.

The nominated alternator is the HCI 534E, Winding 311, fitted with PMG + MX341 type AVR. This alternator has a sustained three phase short circuit current of 2600A.

This alternator has an Industrial Class 'H' temperature rise continuous rating of 600kVA at 400V, 50Hz.

This alternator will support the motor running at rated shaft power of 420kWm, whilst absorbing 560kVA at 0.8pf from the alternator and the Generating Set will absorb some 480kWm from the engine.

ELECTRIC MOTOR SOFT STARTER MODULES

Electric motor Soft Starter Modules incorporate power electronic devices that control the level of initial voltage applied to the motor's windings, which in turn, reduces the motor's inrush current.

Once the motor is turning and accelerating to speed, the power electronics automatically ramp the voltage up to the normal system voltage, then these power electronics are by-passed, leaving the motor directly connected to the local electrical supply and now the power electronics are stood-down.

This type of motor starting generates harmonic current distortion and so, is described as a Non Linear Load.

Because the motor start is of short duration, it is allowable to have a momentary high level of harmonic voltage distortion on the electrical supply, which is often also being used to power other connected equipment.

A typical motor Soft Start situation will result in a kVA demand of around three times the motors kWm or HP rating.

This Start kVA should be identified and then compared with the proposed alternator's value of sub-transient reactance (X"d) calculated for this motor start kVA. The value of X"d should not be greater than 10%.

Refer to AGN025 – Non Linear Loads, for further details of sizing alternators for motors with Soft Starter Modules.