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Application Guidance Notes: Technical Information from STAMFORD | AvK

AGN 022 – Conditions for Parallel Operation

SYNCHRONISATION

The parallel operation of Generating Sets is common, to share the load requirements between generators or between Generating Sets and the utility supply (Mains Grid System). Generating Sets must be synchronised with each other for parallel operation and specific requirements must be met to ensure a smooth synchronisation process.

It is imperative that, at the instant of closing the synchronising Circuit Breaker, the transient current surge experienced by the in-going Generating Set does not exceed 50% of that generators rated current. Achieving this critical requirement will limit the forced levels of synchronising alignment torques experienced throughout the Generating Set equipment component parts. For example; the mechanical drive line, the stator winding assembly and the rotating diode assembly's component parts. Poor synchronisation will impact the in-service life of the equipment package.

Synchronisation with transient current surge <50% of rated current is possible if the guidance and synchronisation window are followed. For a parallel running network consisting of less than five units, but accepting that each unit may have a different kVA rating, then the following well established practice should be conducted.

The Generating Sets that are to be synchronised must be appropriately set during commissioning and this should involve the No-Load voltage levels of the generators to be set within 1V of each other by use of one calibrated true rms meter.

Each Generating Set should be operated at rated load and the level of quadrature droop set to the same level, typically 3% for 0.8pf. The same care and close tolerance levels should be

adopted for setting the engine No-Load speed and also the same level of On-Load speed droop.

Remember; the engine power provides the kWe, the excitation level provides the kVAr, they combine to ensure the paralleled Generating Sets will equally share the supplied kVA and so operate at the same power factor.

The Required Synchronising Window

It is essential that the phase sequence of the incoming Generating Set matches that of the Point of Common Coupling (PCC) bus bar and also that all of the following conditions are met before the Circuit Breaker of the incoming Generating Set is closed on to that bus bar.

- The frequency must match within 0.1 Hz
- The rate of change of frequency must be within 0.1 Hz / second

This *'rate of change of frequency'* is very significant, as an unstable and erratic engine speed (e.g. a cold gas engine), produces a circumferential rotational speed, which accelerates and decelerates in a fast oscillatory manner. Such an unstable running condition may satisfy a 'Rate of change of frequency' monitor considering an average condition and so, may allow synchronisation to take place under a momentary situation where, in fact, the Generating Set's rotor is grossly miss-positioned. This will result in a compensating, very high 'alignment' torque, which can damage mechanical components within the generator or the engine to generator drive/ coupling system.

- The voltages must match within 0.5%
- For the Circuit Breaker closing angle, refer to the following guidance:

If the Generating Set is to be synchronised regularly – daily – then setting to close limits will result in lowest possible stress and therefore, resulting in Generating Set longevity. The Circuit Breaker closing angle must be **< 5deg.**

If the Generating Set is infrequently synchronised – put in synchronism and remains operational for many weeks before being again synchronised – then the Circuit Breaker closing angle must be **<10deg.**

The actual point of synchronising Circuit Breaker closure should result in a minimal current surge from the 'forced' alignment of the two connected systems. This minimal current is advised as being no more than 50% of the Generating Set's rated output current.

To achieve 'minimal current' the synchronising equipment's control system must incorporate a 'rate of change of frequency' monitoring capability. This enables a predictive function with regard to ensuring the moment of closure occurs within the closing angle window and the angle is dynamically decreasing towards the optimum zero degrees - rather than an increasing angle.

The use of old technology synchronisers, which incorporate phase locking technology and so has no 'predictive' capability should be avoided. In fact, where unstable gas engines are used, such low technology synchronisers should never be used.

During commissioning, the time delay between synchroniser issuing the command to close the synchronising Circuit Breaker and the time for this instruction to be followed must be identified. Typically it can vary from 40 to 100ms and the predictive part of the synchroniser package must be set to take this 'closing time' into account.

A variety of proprietary equipment packages are available for synchronising a Generating Set by automatically considering the above parameters and issuing control signal commands to control systems of both the engine and alternator to achieve ideal alignment and so, perfect synchronising with minimal imposed stress to any of the Generating Set components.

Mis-Synchronisation of Generating Sets

Failure to create and maintain the above four listed conditions at moment of closing the synchronising Circuit Breaker will generate excessive mechanical and electrical stresses, which may not be immediately apparent, but nevertheless will become additive and eventually result in equipment damage.

At the instant paralleling occurs; if any one or more of the above conditions has not been matched there will be an immediate transfer of power / energy between the two systems that have just been paralleled, or forced together, in an attempt to create total system equilibrium. When achieving this system 'equilibrium', a correction to the phase angle alignment between the two systems is required and therefore an immediate change to the relative physical position of the alternator's rotor / stator alignment is required.

As a rotor is instantly forced into the correct relative alignment (like electrical gear teeth being forced into mesh), this means that the engine crankshaft via the coupling is also rapidly forced into a new rotational – correct alignment position. Such rapid acceleration / deceleration forces stress on the whole mechanical drive train, with obvious resulting torque reactions present within the alternator stator windings, core pack, frame and feet, to the Generating Set's bedplate, flywheel housing and engine block and feet.

Under the forces that mis-synchronisation imposes onto a system the alternator stator and rotor will be subjected to transient voltage and current levels several times the normal rated designed conditions. As a consequence of the transient stator / rotor mutual inductance conditions, there will be the generation of high voltage spikes in the rotor winding, which could cause a breakdown to the P-N junction of one or all of the rotating diodes. To prevent the diodes from being damaged, the rotating diode assembly incorporates a Surge Suppressor [VDR], which often becomes sacrificial in its endeavours to limit the level of the transient voltage and so safeguard the diodes.

Any occurrence of mis-synchronisation always subjects Generating Set components to high stress levels and must therefore be avoided. For reasons of safety and damage assessment, any occurrence of miss-paralleling should be investigated to ensure it will not re-occur and

then any signs of components having suffered from mechanical or electrical stress damage must be observed.

Inspection of mechanical components becomes a visual inspection for component stress or assembly relative movement, whilst the electrical components should be visually inspected, insulation values measured, and rotating diode assembly checked. Then run the Generating Set under progressively increased load up to rated, whilst monitoring the alternator's excitation voltage, comparing these newly measured values with those recorded in the plant maintenance manual, established for normal site duties during commissioning. Alternatively, refer to the alternator manufacturer's design data, published in the Technical Data Sheet.

DEAD FIELD PARALLELING FOR GENERATING SETS OPERATING IN PARALLEL

Standard synchronisation technique usually follows the procedure where the first Generating Set is energised to the Point of Common Coupling (PCC) bus bar, followed by the synchronisation of the subsequent Generating Sets to the PCC.

There is also another established practice, however; to parallel Generating Sets by using a simultaneous build-up of their excitation and so achieve dead field paralleling of several Generating Sets onto a common 'dead' bus-bar.

This practice is common place for appropriately designed systems used as mains failure units at hospitals on mainland Europe, where the expectation is that a stand-by system must be in readiness to accept load in the shortest possible time and often on more than 8 seconds is specified.

For AvK and STAMFORD alternators with digital AVRs, excitation build-up can be achieved in programming the AVR setup.

For STAMFORD alternators with analogue AVRs, the control system for such equipment incorporates an isolated switching contact (rated at 10A; 240V) for each alternator AVR's K1 - K2 connections.

The K1 - K2 inter-connection is kept open circuit while the Generating Sets are all simultaneously started and run up to rated speed.

Once at speed, an output contactor for each Generating Set is closed, such to connect each running Generating Set onto the common 'dead' bus-bar.

When all the output contactors have closed, indicating all Generating Sets have started and are running at required rated speed, the K1 - K2 contacts for all the AVRs are simultaneously closed.

This causes all the alternators to simultaneously excite and therefore, a (generally) simultaneous build up to their pre-set working No-Load voltage, thereby forcing the necessary

gentle adjustment in phase angle relationship and so self-synchronisation and so parallel running of all the Generating Sets.

Once the bus-bar voltage is detected, the output Circuit Breaker can be closed, thereby connecting all loads to the Generating Sets.

Note; The above synchronising procedure has been tried as a method of paralleling Generating Sets with 'live' bus-bar (Mains Grid System). The tests were unsuccessful, because they resulted in failure of components associated with rotating diode and protection suppression devices.

CIRCULATING CURRENTS IN PARALLEL OPERATION

The pre-requisite for parallel operation is to have the same AVR set voltage level on all alternators. Generating Sets working in parallel with different AVR set voltage levels will cause circulating currents to flow.

Parallel operation of alternators with dissimilar winding pitches can result in circulating currents. All STAMFORD alternators and some AvK alternators are wound with a 2/3rd winding pitch with minimal triplen harmonics. There is no basic reason why any system consisting of these types of alternators cannot have their star points interconnected and in turn, the Neutral link continued to the distribution network's Neutral (star point) connection at the Point of Common Coupling (PCC). Refer AGN 045 – Alternators for Parallel Operation, for information on dissimilar winding pitches.

If during commissioning, it is found that apparently unexplained 'neutral' currents are flowing, then this may well be a product of the characteristics of the connected load that is being supported on this local network. Alternatively, it may be a function of unbalanced voltages across the Mains Grid System - supply network – to which the Generating Set is paralleled.

In the real world, some circulating neutral current is inevitably present. So, if some neutral current is present is it harmful? The simple answer is 'no'. The answer is 'no', providing it does not cause the alternator's designed rated output current to be exceeded through any part of its windings. Obviously, it can be reasoned that the unwanted neutral, or circulating current, is adding to the overall operating temperature of the alternator, which in turn is having a thermal degradation effect on the insulation systems life, but the thermal degradation can usually be reasoned to be minimal if the rated line current is not being exceeded. It should be cautioned that neutral current can be caused by unbalanced loading of the three phases of the alternator, which will cause additional electrical and thermal stresses on the damper windings on the rotor.

The situation regarding Generating Set's being REFERENCED to EARTH and this by 'Neutralising' the Generating Set's star point to other Generating Set star points, is a decision that will need to be based on the specific expectations for individual installations and will be specific to: the on-site Electrical Protection Equipment and the characteristics of the local site load. Here the single phase content must be understood and of course, the intended role of the generating plant. When operating in parallel with the Mains Grid System – supply network

– the local host REC will advise the required situation based on their protection system employed for that section of their network.

Generating Sets operating in Island Mode

When the Generating Sets are operating as an 'islanded' unit, then most definitely the system will have to be 'referenced' and the method used, dependent upon the protection system employed for this duty.

The following additional consideration must be taken in to account for small islanded systems of up to 5 paralleled Generating Sets:

- Expect some circulating currents (kVAr) to occur if two parallel Generating Sets are running under a No-Load condition, as synchronous alignment effort is dynamically present until a level of connected load is applied.

- Circulating current (kW) will occur if the engine speed governing characteristics are not very similar. Once the Generating sets are connected to a common load, however; this will reduce.

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