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Application Guidance Notes: Technical Information from STAMFORD | AvK

AGN 018 – Regenerative Loads & Reverse Power

REGENERATIVE LOADS

Certain loads feed-back mechanical power to an electrical supply system as a characteristic of their normal mode of operation, examples being; a building lift/elevator may have a regenerative braking system to slow and stop at each floor level, or a Crane hoist motor may use electrical braking to slow the speed of a load being lowered.

Other connected loads sharing the same electrical system may absorb this ‘reverse-power’ and so the Generating Set may only have to reduce its contributed power output level during these ‘reverse-power’ occurrences. But situations can occur where the level of ‘reverse-power’ actually exceeds that being consumed by other connected loads and so, regenerated power is actually pushed into the terminals of the alternator.

Under such conditions the alternator acts as a transducer and converts this electrical reverse-power into mechanical reverse-power, by becoming a motor and pushing power into the engine crankshaft. The alternator is not 100% efficient and so some power will be absorbed as losses within the alternator, but the majority of the reverse power will be converted into mechanical power and ‘passed on’ to the engine. This reverse power will cause the engine speed to rise above the engine governor’s speed setting, which in turn will respond by reducing the fuel supply injected into each cylinder.

With no fuel being supplied, the engine will now be spinning as a ‘Pump’, in turn, being driven by the alternator acting as a motor, being powered by reverse-power.

The typical ‘Pumping Losses’ quoted by engine manufacturers is around 10% of the engines rated kWm. So, if the reverse power exceeds the combined alternator losses, plus engines pumping losses, typically identified as being around 15% of the generating set’s kW rating, then the rotational speed of the alternator rotor and engine crankshaft will increase – the reverse power has to do work.
Any increase in speed will result in an increase of electrical system frequency (Hz) and so now the connected electrical equipment is also at risk of damage due to the systems increased operating frequency. An over-speed and therefore, over Hz, condition should be detected by the Generating Set’s own over frequency monitoring detection and protection module and once activated, this should trip the Generating Set. It should be noted that the system voltage is likely to stay very close to nominal, because the AVR will always strive to Automatically Voltage Regulate at the ‘set’ voltage level. This activity is not changed by an over-speed situation because an AVR is not capable of sensing an over frequency situation. Note: all AVRs can detect under frequency.

To avoid a runaway speed condition due to ‘reverse power’, any electrical load with a reverse power characteristic must be identified before the Generating Set specification is finalised and the engineered response to ‘reverse-power’ must be dealt with at the planning stage.

Establishing that the Generating Set’s base load will always be sufficient to absorb the expected levels of reverse power is the first step. But then considerations must be given to data relating to the rate of ‘rise & fall’ of reverse power levels, which must then be considered in conjunction with the dynamic response of the engine governor and the alternator’s AVR, to ensure the system does not become unstable. Such considerations are often complex.

The most practical solution for dealing with high levels of reverse power is to fit the Generating Set with a Reverse Power detection unit and when such situations are detected then activate the connection of ‘Dump Load’ in the form of a correctly rated resistive load bank incorporated as part of the electrical equipment package with the Regenerative / Reverse Power characteristic, such that the troublesome regenerative power is absorbed.

Key Point.

If the other loads are not more than the regenerative load element, then it is necessary to fit additional continuously rated load banks to absorb the excess regenerative power.

<u>REVERSE POWER</u>

<u>Real Power (kW).</u>

When alternators are operating in parallel with other alternators, or a mains supply, situations can occur that result in an alternator absorbing power from the network.

Such occurrences are almost always the result of a malfunction of that alternator’s components. For example, the engine may have run out of fuel and so the alternator runs as a synchronous motor and drives the engine at rated speed. A malfunction of the engine’s power controller could also result in a reverse power situation.

When determining the setting for Reverse Power protection equipment, the engine and the associated pumping losses will be the critical limiting factor and therefore, the engine manufacturer should be consulted in order to provide actual figures for the maximum reverse power capability.

A synchronous alternator can operate as a synchronous motor and providing the stator winding current levels do not exceed the nameplate values, the alternator is not at risk. Under such 'motoring' conditions the developed shaft power (kWm) will be a product of the level of 'controlled' excitation being applied by the AVR. The expectation is that the 'motors' load will have a torque demand such that rated speed is maintained, but not exceeded! Such a controlled 'motoring' condition is hardly likely to occur with unexpected and transient reverse power conditions.

Reverse kVAr (Apparent Power, therefore, watt-less).

Condition 1.

When alternators are operating in parallel with other alternators, or a mains supply, an operating condition associated with very low levels of excitation can result in the alternator actually operating at a leading Power Factor and effectively absorbing kVAr from the connected power source. Under such conditions the low level of excitation results in the alternator's synchronised 'link' to the network being very weak and subsequently, there is a distinct risk of pole slipping occurring.

Condition 2.

Solo running alternators supporting leading Power Factor loads***** are at risk of 'self-excitation' due to the effects of mutual inductance generated by the armature reaction of the leading Power Factor load's current waveform preceding the generated voltage waveform in each phase of the stator winding. A typical alternator can tolerate some 30% of rated name plated kVA in terms of zero Power Factor lead kVAr, before excitation system stability is lost and the alternator's output voltage begins to rise and then is totally outside the control of the AVR. This can result in the alternator's output voltage rising to some 180% of rated output voltage. Such a condition is not really damaging to the alternator, but most certainly will be to the Generating Set control monitoring equipment and most certainly a dangerous situation for the connected load.

If leading Power Factor load conditions are likely to occur – in either conditions 1 or 2 - then the alternator's Operating Chart, also known as a Capability Diagram, must be studied. This will provide guidance regarding the levels of leading Power Factor that will be acceptable and ensure operation is within stable excitation levels.

***** Loads with a potential for creating a Leading Power Factor characteristic are those that incorporate capacitors.

Examples.

1. Discharge Lamps almost always have capacitors in their ‘ballast’ circuits. If a hot discharge lamp momentarily loses its supply, it may not immediately re-strike when the supply is restored. This leaves the supply connected to just the lamp’s ballast circuit and so an impedance with a leading Power Factor characteristic. Such loads should be carefully considered when a mains failure, and thus, standby alternator is going to be connected to hot discharge lamps.

NB; Lamp manufacturers do have options to help with this well-known problem situation.

2. Harmonic filters associated with Non Linear Loads incorporate capacitors and their potential for subjecting an alternator to a high level of leading kVAr load should be investigated.

3. Power Factor correction equipment is often part of the normal electrical equipment encountered on an industrial site. Modern Power Factor correction packages are often intelligent and dynamic, but their response time can sometimes be quite slow after a load reduction event and a leading Power Factor condition can be present for minutes. If such Power Factor correction equipment is in the list of identified loads, then the maximum level of kVAr should be established and compared with the proposed alternator’s Operating Chart. If the possibility of excitation system instability is identified, then it is advisable to ask for this load to be disabled under alternator supply conditions.

Generating Set Protection Modules.

The availability of cost effective electronic Control and Protection Modules offer the availability of Reverse Power detection and Reverse kVAr detection.

A solo running alternator supporting a leading Power Factor load can activate the Reverse kVAr detection module, because this detection element is being ‘fooled’ by a kVAr in the leading Power Factor quadrant.

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