Application Guidance Notes: Technical Information from Cummins Generator Technologies

# AGN 150 – High Intensity Discharge Lamps

## DESCRIPTION

AGN025 provides guidance on Non Linear Loads and AGN026 covers aspects of voltage distortion. There are many commonly encountered Non Linear Loads. There are NLLs that consume discontinuous current associated with power electronic devices; examples being: Variable Speed Drives (VSD), Motor Soft Start Systems and Uninterruptible Power Supplies (UPS). There are also NLLs that consume continuous current; such as lighting units associated with high intensity discharge lamps. Here, we are concerned about the aspects of supplying power to high intensity discharge lamps.

## Family groups

High intensity discharge lamps may have a primary medium of Mercury, Sodium, Metal Halide or Fluorescent Powder.

## Identification and typical applications

### Mercury

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| Colour | Blue light. |
| Application | Internal Hi-bay lighting, but generally over internal and external work areas. |

### Sodium

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| Colour | Yellow light. |
| Application | Street lighting, Outdoor car parks, Green houses. |

**Metal Halide**

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| Colour | White light. |
| Application | Sports stadiums, Work / activity areas where it's important to provide good colour recognition. |

**Fluorescent.**

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| Colour | White towards bluish. |
| Application | Internal offices, factories and shops. Areas requiring Hi-lumens at low cost. |

## LAMP CHARACTERISTICS

A high intensity discharge lamp requires a control system to provide starting and running voltage levels for appropriate control of the lamp's current. This control unit is usually referred to as the ballast and this consists of a choke, a starter and a capacitor.

When these lamps are initially connected to a power supply the ballast will automatically generate a high voltage to be used in conjunction with the lamps igniter circuit, to initiate the process of ionising the gas and begin the process of lamp illumination. From cold, the operating power factor of the mercury, sodium or metal halide lamp's circuit will be at a low lagging power factor, typically 0.6pf. The power factor gradually improves as the lamps brilliance increases, such that at full working temperature and so designed lamp brilliance, the operating power factor will typically be 0.95 to 0.98 lagging, with this situation being achieved within 15 minutes after the initial switch-on.

Some modern high technology lamps are offered with active ballast units, which provide sophisticated current control of the lamp under cold to hot operating conditions and under the typical mains supply voltage regulation of +/-5%. As a result of this active control, the operating power factor is always maintained at some 0.96 to 0.98 p.f. lagging.

If a hot mercury, sodium or metal halide lamp is switched off and then back on again, whilst the lamp is still hot, the lamp system will not immediately re-strike, unless fitted with an electronic igniter. This means that a lamp without a special 'hot' igniter system will only have a power factor correction capacitor in circuit and until the lamp does re-strike, the load associated with this lamp will be Zero p.f. leading.

Consider a situation of many connected lamps with only their capacitors actually drawing current. This presents the power supply with a high level of kVAr leading power factor load. Such a situation can be a major problem for an alternator, because of the inherent characteristic of leading power factor load current causing 'self-excitation' of the alternator. A situation where the alternator could be connected to 30% of rated kVA, being leading power factor kVAr, will result in the AVR losing control of the alternator's output voltage level, which will rise to dangerously high levels; typically 1.5 x normal operating voltage.

## ALTERNATOR CONCERNS

### Leading Power Factor

If the alternator is supplying a combination of other loads under a situation of 'lamps too hot to re-strike', then the resultant total load – kVA and kVAr – on the alternator may well have a power factor close to unity and so, there will not be an unacceptable level of self-excitation. In this situation, allowing the alternator to remain positively under AVR control, thereby ensuring an output at the nominally required voltage. However, if the total load has a distinctly leading power factor, then problems with self-excitation are a risk and the situation must be evaluated by due reference to the alternator's Operating Chart (as known as Capability Diagram). Refer to AGN004 for details.

### Supply Quality

Alternators, especially those of up to 10kVA, have a tendency to generate quite a high level of harmonic content within the fundamental (50Hz or 60Hz) output voltage waveform. This can have an adverse effect when alternators supply a load that includes any frequency sensitive components, such as transformers, chokes and induction motors (examples of components with inductive lagging power factor characteristics) and capacitors (a component with leading power factor characteristics). These examples of loads, which are supply frequency sensitive, makes them very susceptible to any harmonic content contained within their supply voltage waveform.

It must also be appreciated how susceptible a discharge lamp, with its ballast circuit and lamp/tube ionisation process, is to the 'quality' of an applied voltage waveforms Total Harmonic Distortion (THD%) content. This also includes the effect of variations or fluctuations of supplied fundamental frequency, resulting from engine type and engine governor characteristics.

### Harmonics

Discharge lamps operate by creating and controlling electron flow within a gas, thereby, an ionization process. This total lamp circuit package and the ionisation process becomes a load that generates harmonic current distortion and is therefore, a Non Linear Load (NLL).
Typically, a mercury, sodium, or metal halide lamp will operate with 15% harmonic current distortion (THD %) when cold and this will reduce to some 10% once the lamp reaches full working temperature and brilliance.

A fluorescent tube has some 7% current THD% when cold, falling to 5% when hot. The dominant harmonic of all these types of lamps is the 3$^{rd}$ harmonic and this makes for a major 'watch out' when powering a bank of lamps from a three phase distributed supply, because the distribution systems neutral conductor will end-up carrying a higher than rated line current due to the 3$^{rd}$ harmonic currents summing together in the common neutral conductor.

**Any type of NLL will distort its supply Voltage Waveform.**

If the level of harmonic voltage distortion becomes too high, then the ‘forced’ current flowing through the lamps ballast circuits and the ionised gas, will be higher than the lamps designed levels, due to the above described susceptibility of certain electrical components to frequency and harmonics can be considered as ‘extra’ frequencies, superimposed within the supply systems fundamental 50Hz or 60Hz.

If the level of harmonic distortion superimposed within the a.c. voltage waveform is allowed to become too high, then the voltage waveform becomes very distorted and no longer resembles the classic sine wave shape, resulting in ‘extra’ current being forced through the lamp circuits. This situation; at best will ‘over-current’ trip their supply circuit breaker and at worst can cause catastrophic failure of the lamp components, which can result in a fire.

Installations where even reasonable levels of harmonic distortion occurs will affect the ‘purity’ of the emitted light and in common with an unstable Generating Set running speed, engine cyclic irregularity, or excitation system instability, will promote supply voltage variations and the net result is lamps giving a ‘flickering’ light, which is found to be most unsatisfactory to the human eye.

**Generator Choice & Excitation System**

The standard recommendation for alternators to be used for NLL applications is to carefully consider the alternator’s source Impedance in terms of calculating the sub-transient reactance (X”d) related to the level of NLL kVA.  This enables a level of risk to be identified regarding the effect the connected load will have on the supply systems level of harmonic voltage distortion.

The acceptable value of X”d becomes very subjective with regard to each application under consideration of the total site load to be supported and so the maximum level of harmonic voltage distortion that is considered to be acceptable.

**Rule of Thumb.  Don’t allow the X”d to be above 8% when calculated to a base level associated with the total connected kVA of lamps.**

With regard to the excitation system, we must ensure the alternator’s excitation system remains stable under the imposed levels of harmonic distortion created by the NLL, an isolated and so stable power supply must be incorporated within the alternator to provide the AVR with an excitation power source.  Ideally this should be based on a PMG pilot exciter, although a well-designed auxiliary stator winding can provide acceptable levels of performance.

**Rule of Thumb.  An MX type or Digital type AVR should be nominated regardless of the calculated level of harmonic voltage distortion.**

If the alternator has to support an array of lamps that are distributed across a three phase system – adjacent lamps in work areas should always be distributed across a three phase system to reduce the stroboscopic effect – then the nominated AVR should include three phase sensing capability; therefore an MX321 AVR.