STAMFORD | AvK ™

POWERING TOMORROW, TOGETHER

Application Guidance Notes: Technical Information from STAMFORD | AvK

AGN 016 - Negative Phase Sequence Currents

DEFINITION

Positive Phase Sequence.

If an alternator is supplying power to a linear, balanced load, this is described as having a Positive Phase Sequence and is considered as being a normal condition.

Negative Phase Sequence.

If an alternator is subjected to an unbalanced load situation, connected to non-linear loads or an asymmetrical fault condition, then the resulting state is described as having a Negative Phase Sequence component. Under these conditions, a Negative Phase Sequence Current [symbolised as I_2] will exist.

ACCEPTABLE LEVEL OF NEGATIVE PHASE SEQUENCE CURRENT

Alternators manufactured by STAMFORD | AvK are designed to comply with the performance standards in IEC 60034-1. There is lengthy reference to an alternator's capability to cope with unbalanced loads and therefore an ability to cope with a negative phase sequence condition, with stipulation that the minimum expectation for the alternator is that it will cope, at least, with a continuous condition of 8% Negative Phase Sequence Current [I_2]. The per unit relationship of Negative Phase Sequence Current to an alternator's Base Continuous Rating [Class H temperature rise rating full load current for a low voltage alternator] should not continuously exceed 0.08 p.u. [8%]. The consequences of exceeding 8% Negative Phase Sequence Current may be catastrophic.

Consequences of Excessive Negative Phase Sequence Current.

Negative Phase Sequence conditions can occur under stator winding current levels well within the designed stator winding capability and therefore within the output circuit breaker trip level. During conditions of excessively high continuous negative phase sequence components the alternators rotor damper cage will be subject to high continuous current levels and therefore heating beyond its designed capability. If this condition continues, excessive heat is likely in the damper cage, which in turn will heat the rotor lamination steel and burn the winding slot insulation 'paper' from the lamination steel side of the winding.

Under extreme conditions, the damper cage will get hot enough to melt the damper bars and this molten material will throw out onto the stator winding, causing catastrophic damage to the alternator.

Unbalanced loads / none linear loads across the three phase output from an alternator can also cause operational problems to other connected loads. An unbalanced loading across three phases will result in an unbalanced three phase voltage being supplied to other three phase loads, with the result that these loads will suffer a degree of component degradation, which may eventually result in premature failure.

ALTERNATOR DESIGN CONSIDERATIONS

Cummins Generator Technologies have considered negative phase sequence condition capability in each alternator's design, such that the damper cage can tolerate up to twice the required 8%, let's say 15%. The rotor will get hot but should not be subject to premature failure. For the purposes of setting negative phase sequence protection, however; equipment should be set to the 'text book' value of 8% to ensure reliable and safe operation.

CALCULATING NEGATIVE PHASE SEQUENCE CURRENT

Simple Method to Calculate Negative Phase Sequence Current.

This simple equation effectively identifies the I_2% level for a real load situation against the alternator's designed I_2 capability.

Consider an alternator with a Class 'H' temperature rise continuous rating at 100A per phase, but which has actually been installed and specified to operate at 90A per phase. Due to the variation in load types, an unbalanced load condition exists, where the alternator is in fact, operating at:

U-ph = 70A, V-ph = 50A, W-ph = 45A.

Method.

To identify I_2%:

1. Calculate the value of the lowest phase current as a % of alternator's rated current, and then the highest phase current as a % against rated current.

2. Subtract the % value of the lowest phase current from the % calculated for the highest phase current.

3. Divide the % difference by 3.

Example Calculation:

1. The highest phase current % = {[70A/100A] X 100} = 70 and the lowest phase current % = {[45A/100A] X 100} = 45.

2. 70% - 45% = 25%. The alternator is supplying an output with some 25% imbalance of its Class 'H' rated current.

3. To establish the level of Negative Phase Sequence current component associated with this unbalanced load condition: Divide this 25% by 3. Negative Phase Sequence Condition is therefore approximately 8%.

For further guidance on Unbalanced Load conditions, refer to **AGN017 Unbalanced Loads**.

Power System Design Method to Calculate Negative Phase Sequence Current.

The simple example above has resulted in an answer a lot closer to the *Real answer* than would normally be the case. The above example uses an approximation method and must not be taken as the absolute answer with regard to system design.

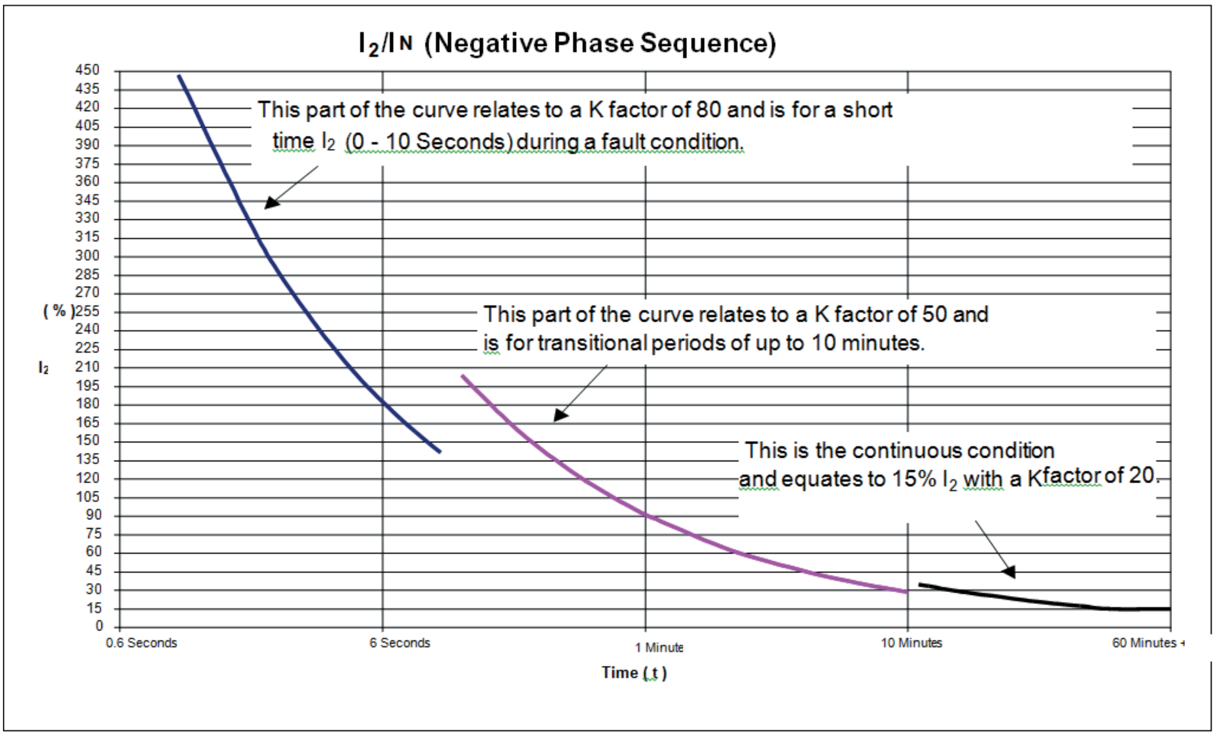
The standards of course correctly state that the heating effect of any negative phase sequence condition is a product of amount of I_2 and the time duration of the I_2 event. The standards also take into account that the heating effect is the product of the square of the current [I_2], which is written in the standards as;

> [I_2 divided by the alternator's rated rms current]^2, times the time period of the I_2 event in seconds.

The standards further state that the answer to this sum equals a constant, usually called K, which they set at 20.

It must be accepted; it is important to be able to set the protection equipment to take into account the fact that; following an event above the 8% level, there must be sufficient time for the damper-cage to cool down before the next negative phase sequence occurrence. If the next event occurs almost immediately, then this will add to the heat already present, and although not over the negative phase sequence current limit, it will take things over temperature.

For this reason, we must introduce a cooling curve characteristic. Here the cooling curves typically follow an exponential characteristic where the 0.632 factor is used, with a typical time 't' for a damper cage: say 30 seconds.



Negative Phase Sequence

A Brief Discussion follows about what the Standards say and where we are with alternator ratings today.

We are often challenged about the 'good old days of 30% asymmetric current' and why don't we still say this in our literature. Well actually this does align reasonably well with the values stated in the Standard [IEC 60034 -1], which state that for a Synchronous, indirect cooled, type of ac generator, it must cope with 8% Negative Phase Sequence Component of Current.

In the 'good old days' machinery was not operated too closely to its designed limit; often Class F temperature rise ratings were the norm. This resulted in a family of alternators that had Negative Phase Sequence Current capability in line with the expectations of the day and this was for an I_2 capability of 30%, which would mean a phase current unbalance of 90%.

Today we have the same rotor design and so damper cage construction, but now we have fine-tuned the overall alternator design to give higher output kVA from a given active material package. The Negative Phase Sequence Current capability; however, remains at the originally designed level of I_2 amps, which related to the alternator's increased output current is now a lower I_2%. I guess you could say that the people who write the Standards know the problem and so reduced the I_2 % level.

stamford-avk@cummins.com
www.stamford-avk.com

STAMFORD | AvK ™

POWERING TOMORROW, TOGETHER