WHITE PAPER

Starting motors on generator sets

Selecting the most effective starting solution

BENSHAW
Applied Motor Controls

How motor starting affects generator sets

During start, an A.C induction motor draws a high current during acceleration before dropping back to its run current. The magnitude of a motor's starting current is dependent upon its rotor design. Typically, a motor's locked rotor current (LRC) will be around 6 x Full Load Current (FLC), but levels above 9 x FLC are not uncommon.

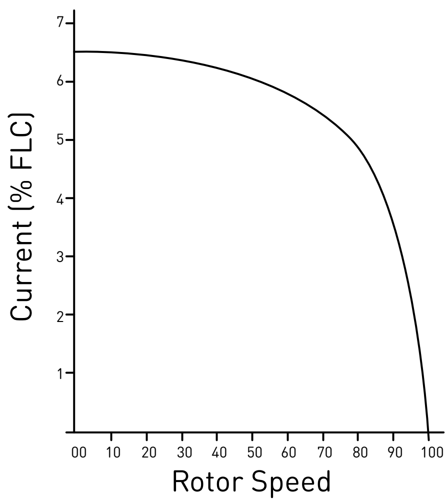

Figure 1: Typical motor current/speed curve

The effect of this high start current is twofold. First, it will cause a voltage drop in the supply, the magnitude of which is dependent upon the supply impedance. Second, it will place a kW loading on the supply which means physical work for the engine at the generation plant.

These same events will occur on a generator set supply, but the implications are significantly greater. For example, for a hydro-power station or similar, the energy required to start any given motor is an insignificant load. In contrast, for a generator set, the energy required to start a motor can be significant in relation to its total capacity.

Motor starting current often accounts for a large proportion of a generator set's overall loading, raising a number of important considerations when seeking an efficient and cost effective solution.

MAXIMUM LOADING

Where A.C. induction motors are a sizable part of a generator's loading, the energy required to start the motor will be a major factor in determining generator sizing.

With respect to the alternator, the full voltage start current of a motor will typically be six to nine times higher than its running current. This places a high kVA loading on the alternator during motor starting. The alternator must be capable of meeting this temporary overload. The total kW loading on the generator engine during full voltage starting is the sum of the 'shaft kW' plus the I2R loss in the motor and alternator. Typically, the I2R losses will be 50% to 100% of the motor kW rating and will remain constant throughout the start. The generator engine must be sized to have sufficient capacity to maintain speed during the starting overload.

Reducing the voltage applied to the motor during start will reduce both the kVA loading on the alternator and the kW loading on the generator engine provided that the means of reducing the voltage does not significantly add to the losses.

In short, reducing start current with an appropriate reduced voltage starter may allow selection of a smaller generator in new installations, or allow connection of larger motors to existing generators without voltage or frequency disturbances.

LOAD SHIFTS

To maintain constant voltage and frequency a generator set must be able to accurately track the load. The instantaneous load shifts associated with motor starting place a great demand on the ability of both the engine and the alternator to respond.

For a generator set to supply an electrical current at a stable frequency the engine must rotate at a constant speed. To achieve this, a governing system is employed to vary the input of liquid fuel to the engine. This governing system has a finite response time, yet most motor starting systems subject the system to instantaneous changes. As such, the 'stepped' nature of most motor starting systems can result in severe frequency variations during motor starting.

For a generator set to supply an electrical current of constant voltage, excitation of the alternator must be varied to match the varying load conditions. This is achieved with the use of some form of automatic voltage regulator (AVR). However, there is again an associated response time involved, and applications of load such as those that occur with motor starting can be at a rate faster than this response time.

In such situations there will be a voltage deflection equal to that which would result if no AVR were present. In addition, this can cause an overshoot in output voltage when the AVR reacts to the voltage drop.

Application example: Soft starters are frequently selected for control of ship bow thrusters due to the large size of the motors relative to the generator.

Selecting the right starting method

With the aforementioned effects of motor starting on generators in mind, the ideal reduced voltage starting system for generator sets is one which:

a) Allows start current to be reduced to the minimum level required by the motor to start the connected load, without introducing losses of its own. This reduces the kVA demand on the alternator and the kW loading on the engine.

b) Controls the application of the start current to gradually apply load to the generator at a rate which allows the generator time to respond. This enables the generator set to respond accurately during motor starting, reducing voltage and frequency disturbances.

DIRECT-ON-LINE OR ACROSS-THE-LINE STARTERS

Direct-on-line / across-the-line starters, while simple and cheap, provide no means for limiting start current or controlling the rate of application of load. When using a DOL or ATL starter in a generator application, the generator will be subjected to full motor locked rotor current (LRC) levels instantly upon motor start.

WYE-DELTA STARTERS

Start current is limited while in the wye connection, but there is no control over the level of current. As a result, the motor and load may not reach full speed before switching to DOL state. In such circumstances the generator is subjected to two smaller current steps in contrast to the single large step observed with DOL/ATL starting.

It should also be noted that wye-delta starters do nothing to slow the application of load to the generator set, and more importantly that the transition from wye to delta is an open transition.

This open transition causes severe current and torque transients that are much more detrimental to the supply and mechanical equipment than full voltage starting.

When the motor is spinning and disconnected from the supply it acts as a generator, with an output voltage which can equal the amplitude of the supply. The frequency of this voltage is dependent on the motor speed and decays only slowly during the open transition. At the time of reclose there can still be significant voltage present. As the frequency of the voltage generated by the motor will be less than the supply frequency, there will be an instantaneous voltage difference between the motor terminals and the supply.

The voltage generated by the motor at the instant of reclose may be equal to the supply voltage but exactly out of phase. This equates to reclosing with twice the supply voltage on the motor. The result is a current of twice locked rotor current and a torque transient of four times locked rotor torque. These transients are responsible for many of the supply disturbances and mechanical breakdowns experienced in industry.

PRIMARY RESISTANCE STARTERS

Primary resistance starters dissipate a lot of energy during start due to high current through (and voltage across) the resistors. This is a major drawback for generator set supplies because the energy drawn from the supply will be greater than that supplied to the motor. The extra energy is dissipated as heat by the primary resistance and can be well in excess of the kW rating of the motor.

Primary resistance starters do nothing to slow the application of load to the generator set. The system has two load shifts. The first when stepping from zero voltage to the reduced voltage, and then again from reduced voltage to full voltage.

AUTO-TRANSFORMER STARTERS

Unlike wye/delta or primary resistance starters the auto-transformer starter provides a measure of flexibility regarding selection of start voltage, and thus provides some possibility of achieving a lower start current. However, starting remains a two stage stepped process that does not slow the application of load to the generator set.

Additionally, auto-transformer starters have an inrush current both at start and when switched between taps. These inrush currents can adversely affect the generator's ability to maintain a stable voltage during start.

VARIABLE FREQUENCY DRIVES

Variable frequency drives (VFDs) limit start current, slow the application of load and reduce starting kW and kVA. At first glance this appears to make VFDs an ideal solution for starting motors on generator set supplies, however this is not so.

VFDs introduce voltage and frequency variations that affect power quality. These variations are magnified when the application power source is a genset rather than a utility grid.

The harmonics created by VFDs result in a pulsed current draw that raises the generator's internal temperature. This overheating can prevent the generator from producing its design output at rated frequency. To compensate, generator set manufacturers typically recommend oversizing of the generator for the kVA requirement. This is necessary to maintain a clean supply with stable voltage and frequency.

While the above characteristics may preclude VFDs from being a practical option for the starting of fixed speed motor applications on generator set supplies, their use to control applications that benefit from variable speed is still valid. In this case, careful genset sizing and engineering of the installation should be undertaken to ensure a successful outcome.

SOFT STARTERS

Soft starters provide better control of start current than any other form of reduced voltage starter. In most cases, a soft starter is the ideal reduced voltage motor starting solution for use with generator sets. Their effectiveness can be attributed to four main characteristics.

Flexibility of adjustment

Unlike electromechanical starters, soft starters allow selection of any desired start voltage/current setting. This means that start parameters can be easily configured to suit individual motor and load characteristics.

Direct control of current

Advanced soft starters allow for direct control of current, in contrast to electromechanical solutions that control voltage rather than current.

With constant current or current limit start modes the soft starter dynamically adjusts the voltage to maintain the desired start current. This allows the start current to be set to the absolute minimum for the given application.

Higher motor torque

The direct control of current provided by soft starters results in increased motor torque during start when compared to electromechanical starters.

Electromechanical starters deliver a constant voltage that reduces start torque throughout motor acceleration, whereas with soft starters the ratio between DOL current and start current reduces as the motor accelerates.

The significance of this effect is evident when the speed/torque curve of a typical load is matched with the speed/torque curve of a motor starting under reduced voltage conditions.

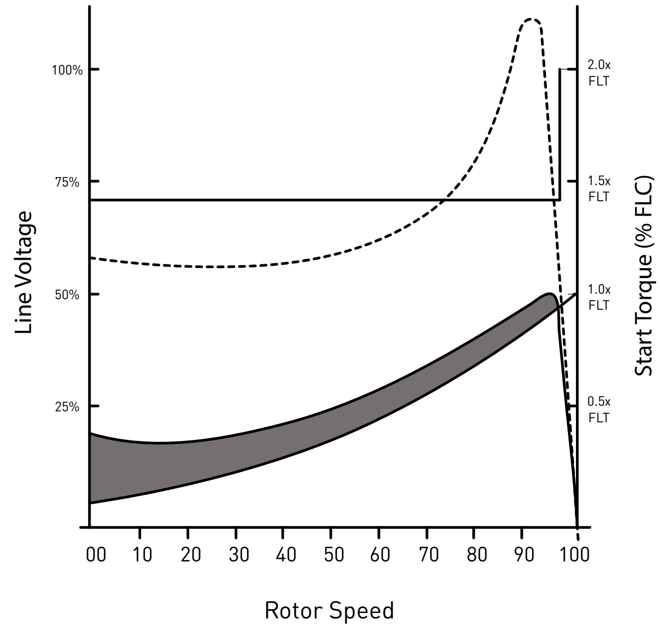

Figure 2: Constant voltage torque curve (shaded area represents available accelerating torque).

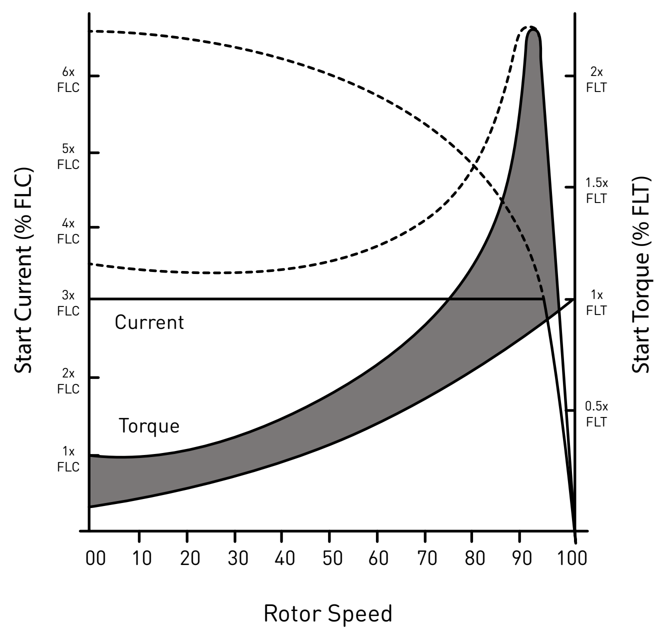

Figure 3: Soft starter current and torque curves (shaded area represents available accelerating torque).

As figures 2 & 3 show, the increasing torque characteristic of motors started with soft starters allows the motor to produce sufficient torque to fully accelerate the motor at a start current lower than that required by an electromechanical starter.

Gradual application of load

Use of solid state switching devices allows soft starters to seamlessly ramp up voltage. In contrast, electromechanical starters must switch or 'step' between voltages.

The smooth ramping of voltage performed by soft starters eliminates instantaneous changes in the loading placed on the supply. For generator sets, this means that the generator's automatic voltage regulation (AVR) system and the engine's governing system are given more time to respond during motor starting. This enables better regulation of both voltage and frequency during start.

In addition to offering gradual changes in voltage rather than instantaneous steps, most soft starters also offer a current ramp start mode. Like constant current starting, a current ramp start (figure 4) dynamically adjusts voltage to maintain a pre-set start current, but also allows a gradually increasing start current profile to be specified.

The current ramp start mode is beneficial in generator applications where it can be used to further slow changes in loading.

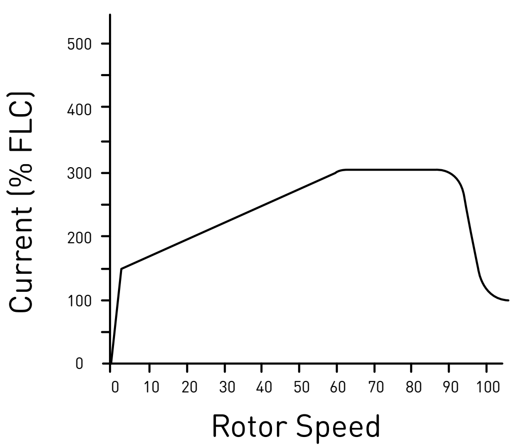

Figure 4: Typical current ramp soft start current profile

SUMMARY OF SOFT START BENEFITS

Correctly engineered, electromechanical starters can be used to reduce motor starting current thereby reducing load on generator sets. However, these starters seldom result in the best possible current reduction and still subject the generator to instantaneous variations in load.

In contrast, soft starters allow easy on-site adjustment of starting performance so the minimum possible start current level can be achieved. Furthermore, soft starters are able to slow the application of load to the generator set. This combination of reduced and gradual loading assists the generator set in maintaining constant voltage and frequency during motor starting.

For generator set users and suppliers soft starting provides the following primary advantages:

- Improved voltage and frequency stability during motor starting.
- The possibility of connecting new motors to existing generator sets with limited spare capacity.
- Reduced generator set sizing for new installations where motors are a significant part of the loading.

Generator sizing and selection

When using a genset to supply motor-starting loads, the interactions are dynamic and complex. For the most reliable and accurate results, the sizing exercise needs to consider the genset as a system, including the engine, alternator, voltage regulator and excitation system, along with motor starters.

Due to the complexity of total system loads and the dynamics of the genset and motor-starting applications, it's important to consult with the genset supplier or utilize genset-sizing software to ensure performance of the entire system in its specific application. Regardless of what sizing method is used, the following fundamental criteria for motor starting must be accomplished to successfully start a motor:

ENGINE KW SIZE

The power & torque available from the genset must exceed the torque & power required by the motor load or the motor will never start.

Actual load start torque and power requirements can be calculated using motor and load speed/torque curves. Contact Benshaw if you would like assistance with this process.

ALTERNATOR SHORT-TERM KVA RATING

The alternator must have a short-term kVA rating such that the terminal voltage does not drop below 15% of the nominal during motor starting. The more start current required for a given motor/load combination, the higher this short-term kVA requirement.

ALTERNATOR CONTINUOUS KVA RATING

The alternator must be capable of providing the required full load current with minimal voltage drop during running.

Summary

As has been shown, soft starters are generally the best solution for starting motors in generator set applications.

In contrast to electromechanical solutions, soft starters apply load gradually and allow the generator time to respond to this load increase. By limiting maximum start current to the minimum required for the motor to start the load, soft starters may allow for reduced generator sizing or the connection of additional motors to an exisiting generator.

Variable frequency drives also limit start current and slow the application of load to the generator. However, unless the generator is oversized relative to the application's kVA requirement, the harmonics produced by a VFD during operation may cause the generator to overheat and reduce its power output, causing numerous problems for motor starting.

This oversizing requirement negates many of the benefits inherent to a reduced maximum start current, limiting the sensible application of variable frequency drives to applications where process speed control is a necessity.

Soft starters typically allow easy adjustment of start parameters, making it simple to set a system for the best starting outcome. However, for new or complex applicatons it is best to carefully engineer the system for the application prior to installation.

Engineering the ideal solution requires an accurate understanding of the start requirements of the given motor and load, including the necessary start current and start time, which must then be matched with the generator's capacity to meet those requirements.

Contact Benshaw for assistance in identifying the start requirements of your motor and load when engineering a solution for a generator application - we're here to help.

Visit our website at www.benshaw.com to get in touch with our team of motor control experts.

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