FAIRFORD ELECTRONICS

SIZING GENERATORS FOR SOFT STARTED MOTORS

There are many instances where it is necessary to start a large motor or motors from an isolated power supply as for instance, on board ship or at a construction site etc. In these situations, the electrical energy is frequently derived from a local generator set driven by a prime mover such as a diesel engine, hydraulic turbine or similar device. Since the capacity of the generator is usually small compared with that of a typical public or large-scale private supply network, these machines are frequently characterised by having relatively high source impedance.

Because of this constraint, consideration has to be given to the effects of soft starting a motor on the generator and on other types of equipment that is also connected to the generator output terminals during the motor starting process.

The essential elements in deciding the size of a generator are: -

1 The characteristics of the largest motor to be started (Speed/Torque/Current relationships).

2 The characteristics of the load of the largest motor to be started (Speed/Torque relationship).

3 The sub-transient reactance of the generator (X”d).

4 The nature of the generator automatic voltage regulator.

5 The sensitivity to supply voltage distortion of any non-motor loads which remain connected to the generator during the motor starting process.

6 The soft starter power circuit configuration.

Taking each element in turn: -

1 Since the objective is to provide an optimally sized system, it is important the motor has an advantageous speed/torque characteristic since this will significantly lower the demands made on the generator during motor starting. An ideal motor would have a high locked rotor torque (LRT) of say, greater than 2 x rated full load torque and a low locked rotor current (LRC) in the region of 5.5 - 6.5 x full load current (FLC). Most reputable manufacturers produce motors with these characteristics. When controlled by a soft starter, this type of motor usually accelerates comfortably and smoothly in approximately 3.5 x FLC.

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2 Many loads have low breakaway torque requirements as, for example, centrifugal pumps, fans, rotary compressors, chillers etc., and can often be turned by hand when stationary. Although these loads place little demand on the power supply at start up and acceleration, it is important that the high inertia loads such as fans, flywheels, crushers are identified, because these applications frequently require an extended length of time to complete the acceleration process. Where a high breakaway torque is required, such as a high friction load, it may be necessary to strengthen the generator in order to deliver enough energy to overcome the initial "stiction". In this case, it is even more important that a motor with a high LRT is used.

3 The characteristic which determines a generator's ability to respond to sudden and large demands in energy output is its "magnetic stiffness", and it is usual to consider the generator's sub transient reactance (X”d) as the indicator of the supply source impedance. This value should be as low as possible contingent with an economically viable package which meets the starting kVA demand plus any limitation in voltage distortion imposed by the type and sensitivity of other connected loads.

Since the starting kVA can be readily calculated from the motor/load characteristics, the main additional influence is the allowable level of voltage distortion. Providing the generator AVR is immune to voltage distortion (see 4 below), the question is limited to the distortion tolerance of the connected equipment, <u>including the soft starter</u>. If the connected load consists primarily of motors controlled by Fairford Electronics soft starters, the tolerance to voltage distortion is high (approx. 35%). Consequently, the degree of generator over-sizing for voltage distortion is significantly reduced, leaving only the initial or impact kVA as being of major concern. As described above (see 1), the motor and load characteristics determine the start kVA - the soft starter only serves to reduce the impact kVA and the torque output of the motor. Nevertheless, it is important to ensure that there is always sufficient torque to allow the motor to accelerate to full speed, - and this can only come from the motor itself.

Non-linear loads can be quite sensitive to voltage distortion and this aspect must be considered when sizing a generator because this may materially affect the value of X”d required. Since the allowable voltage distortion is directly proportional to the sub-transient reactance, the lower the distortion tolerance, the lower X”d has to be - and the more the generator kVA has to be oversized (see 5).

3 The type of automatic voltage regulator (AVR) fitted to the generator is significant since it “looks at” the generator terminals and adjusts the excitation to maintain the voltage at the correct value. If the AVR energy is derived from the generator output, it may be susceptible to voltage distortion and can become unstable. It is important to ensure that the

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performance of the AVR is independent of the generator output waveform and preferably, derived from a separate source such as a permanent magnet generator driven by the main generator shaft.

5 Since the action of a soft starter is to introduce a non-linearity in the current to the motor being controlled, this tends to distort the generator current and voltage waveforms and in turn, may affect any other electronically controlled equipment such as instrumentation, the newer forms of lighting, etc., operating at the same time. The extent to which this equipment can tolerate the resulting distortion will determine to a greater or lesser extent the required X"d of the generator. The following table gives typical voltage distortion tolerance levels for a variety of potentially sensitive loads.

Type of Equipment	Voltage Distortion Tolerance Level
UPS	<10%*
Electronically Controlled Lighting	<15%*
VSD (Inverters)	<15%*
General Electronic Equipment	<20%*
Soft Starters (General)	<25%*
Soft Starters (Fairford Electronics)	<35%

(These values are a guide only and have been found to be acceptable in practice, for accurate information regarding specific equipment, consult the equipment manufacturer).

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To derive a value of X"d for a motor controlled by a Fairford Electronics Optimising Soft Starter (types 3MC, 3MC+, 4MC, 4MC+, 4MCe, QFE, QFE+) the following method should be used:-

Step 1 *Calculate the required starting kVA from: -*

Start factor x motor rated kVA.

(Where start factor = (per unit soft starter pedestal voltage)^2 x LRC factor and LRC factor = Locked Rotor Current (Amps)/Full Load Current (Amps)). [*Can be found in the motor manufacturer's data.*]

For example, applying a pedestal voltage setting of 50% and substituting a typical value for the motor LRC factor of 6, and also assuming a low or zero breakaway torque application, the initial kVA is -

Initial kVA = $(0.5)^2$ x 6 x motor rated kVA = 1.5 x motor rated kVA.

(*NB: to limit distortion, the pedestal voltage should not be set at less than 40% when the motor rated kVA is more than 25% of the total connected load*).

As the soft starter operates, the motor and load will accelerate, the current will become less distorted and will increase in value towards a maximum at about two thirds speed before falling to the normal full-speed load current. Depending on the ramp time, the peak current drawn will be in the region of 3.5 - 4.5 x FLC. If the current limit feature is active, the peak current will be limited to the set value, but the acceleration time may increase depending on the inertia of the load. Consideration must be given to the temporary overload performance of the generator and prime mover during the acceleration phase. As a guide, typical soft starting conditions for a centrifugal pump are a start time of 5 seconds with a current limit set at 3.5 x FLC. For a high inertia fan, the time may be increased to several tens of seconds or even a number of minutes.

If the additional connected load is sensitive to voltage distortion, then the generator kVA will have to be increased by the appropriate factor to compensate:-

Step 2 *Find the X"d appropriate to the <u>minimum</u> level of voltage distortion tolerated by all non-motor loads which will remain connected to the generator supply while the motor is soft started.*

A useful approximation of the generator sub-transient reactance, $X''d_{dist}$, necessary when a 6-pulse soft starter is used to accelerate a motor, is 0.36 x tolerated voltage distortion. So, if the minimum tolerated voltage distortion is 25%, (typical soft starter), then $X''d_{dist}$ = (0.36 x 25%) = 9%.

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Step 3 *Calculate the size of generator necessary to deliver the starting kVA without distorting the supply volts by more than the tolerated amount.*

Using the example given above where initial kVA was calculated to be 1.5 and allowable distortion was 25%, the final size becomes:

$$\frac{1.5 \times 14 \text{ (typical X”d for non-distorting loads) x motor rated kVA}}{X''d_{dist}}$$

= 2.3 x motor rated kVA

However, because Fairford Electronics' Soft starters are designed to tolerate voltage distortion up to 35%, $X''d_{dist}$ now becomes = 12.6, and the generator final size = 1.67 x motor rated kVA only.

The above example demonstrates the need for accurate information regarding loads sensitive to voltage distortion since it is evident that the generator size is quite sharply increased over that needed to start the motor alone. It also shows that distortion consideration only comes into play when the motor being started represents the major part of the total connected load.
Throughout this paper, we have only considered motors being soft started by fully-controlled soft starters, i.e. 6-pulse. Other types such as half-controlled have major disadvantages from the point-of-view of voltage and current distortion due to the more adverse harmonic spectrum developed by the controller. The effect is to greatly reduce the $X''d_{dist}$, which means a more costly machine. For this reason, it is recommended that the use of non-6-pulse and distortion-sensitive soft starters is limited to the smaller motor sizes.

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