Alternative motor starting solution

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Often, the problem faced by engineers when designing a starting solution for a series of large inline motors, like those found in major pumping applications, is the amount of voltage drop, which can have a detrimental effect on other viral equipment within the plant or operation. This article examines an alternative solution to starting large inline motors in order to minimise starting current and reduce associated voltage drop.

Often the local utility company will have some restriction on the amount of voltage drop allowed on the medium voltage (MV) network as this can disrupt the smooth operation of the network and other customers connected to it. It is a well known fact that standard induction motors during Direct Online (DOL) start up can draw as much as seven times the nominal operating current. For larger MV motors, these currents can be quite significant. Also, a motor operated without any control devices, eg VSDs (Variable Speed Drives) function at approximately 0,87 lag power factor while operating at full load. Also during DOL start up, the power factor can drop as low as 0,2 lag.

While VSDs are a tried and trusted solution, what happens when clients request that they only need motor start up and don't require speed control during operation? Nor do they want to pay to replace any existing equipment.

Reactive power compensation

A solution could be the use of fast switching reactive power compensation. The benefit of this type of equipment is its ability to drastically reduce the starting currents and thus help reduce associated voltage drops. This type of system can connect large groups of reactive compensation within the first voltage cycle (20 msec), which helps raise the starting power factor close to the unity and thus reduce the starting current.

Another of the benefits of this solution is its ability to minimise the amount of MV switchgear required, installation and equipment costs. Also, all capacitor switching is done at 'zero crossing' of the voltage waveform so there are no associated voltage or current transients associated with capacitor switching.

All capacitors used in this system are low voltage (690 V) and the reactive power generated is supplied to MV levels using a step up transformer. As all components are low voltage and, as all capacitor switching is done at zero crossing, the electrical stresses on the components are reduced, extending their lifecycle and lessening long-term maintenance costs.

Chosen scenario

To give readers a better insight into how the solution works, we have chosen a scenario tasked with having to start four 1,55 MW motors without exceeding 1,5% voltage drop at 66 kV (typical voltage drop was 4%). The 'client' had engaged engineering consultants to find a suitable motor starting solution for one of its pumping stations for a new irrigation project. The main challenge for the consulting engineers was to find a solution that would only be used for sequential motor starting (to keep costs low) and also would meet the supply authority regulations of a maximum voltage drop of 1,5% at 66 kV.

Initial simulations run by the consultants showed that the voltage drop at the 66 kV network could be greater than the 4%, and there was a need for some form of motor starting solution that was cost effective, simple to operate and maintain, and met the voltage regulation challenges mentioned previously.

Associated high costs

The standard motor starting solutions such as VSDs and MV Soft Starters were considered, but were scrapped due to their associated high costs and complexity (see break-out box). To meet these unique customer requirements, a reactive power support motor starting solution was chosen because:

- The reactive power support motor starting solution demonstrated to be the perfect centralised real-time motor start up solution. A single system can serve four individual motors, therefore proving to be a very cost-effective solution.
- In this case, it met all the requirements for the voltage dip as outlined by the supply authority.
- This solution is versatile enough to add more motors to the system at a later stage without having to change or add any extra components.
- The right reactive power support motor starting solution system, combined with a matching power factor correction system also is able to provide reactive power compensation during normal operation.

In order to optimise the performance of the scenario's facility, increase cost effectiveness, protect valuable equipment, comply with the regulatory authority and correct power factor, a combination of compensation systems were installed at the site.

Provided at the point of connection

The installation outlined in *Figure 1* comprises 1 x Elspec EQ-ST 8,4 Mvar – 690 V system and 1 x Elspec EQ 2,43 Mvar – 690 V system stepped up to 11 kV using 6 MVA, 11/0,69 kV transformer. All compensation support is provided at the point of connection of the motors (11 kV). The solution proved most satisfactory and met additional criteria:

- **Motor start-up:** The consecutive start up of the four motors with no difficulties.
- **Voltage drop:** The voltage drop during start up reduced by more than 60%
- **Start-up current:** The start up current reduced significantly from 580 A to below 280 A.
- **Start up time:** The length of the start up period reduced by 25%: From four - three seconds.

Engineers verified the performance of the reactive power starting technology meticulously and derived at the results in the following tables.

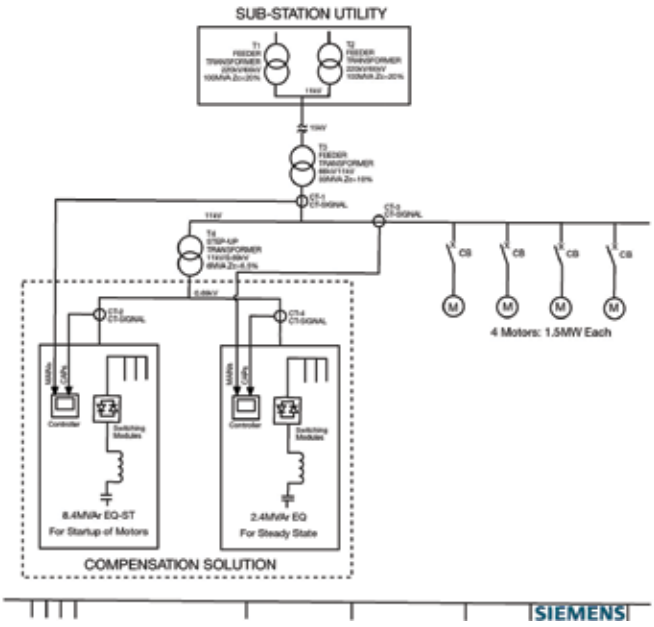

Figure 1: Installation diagram.

PARAMETER	WITHOUT	WITH	IMPROVEMENT
Voltage Drop During Startup at 66kV ΔU %	4.1%	1.4%	65%
Voltage Drop During Startup at 11kV ΔU %	8.8%	2.8%	68%
Total Current at 11kV	580Amp	280Amp	51%

Table 1: With Elspec EQ-ST (8,4 Mvar) – 66% compensation.

PARAMETER	WITHOUT	WITH	IMPROVEMENT
Voltage Drop During Startup at 66kV ΔU %	4.1%	1.15%	72%
Voltage Drop During Startup at 11kV ΔU %	8.8%	2.25%	75%
Total Current at 11kV	580Amp	280Amp	58%

Table 2: Combined Elspec EQ-ST (8,4 Mvar) and Elspec EQ (2,43 Mvar, optional) - 83% compensation.

Table 1 outlines results based on utilising a standalone Elspec EQ-ST system, and *Table 2* outlines results calculated as an optional solution of combined compensation utilising the Elspec EQ-ST and Elspec EQ systems. The following motor starting solutions were considered:

VSD using synchronous transfer

Although on the surface this method proved to be more than adequate motor start up solution, results showed it to be a complex and expensive exercise to start the four motors. Individual power factor compensation systems would still be required for each motor after starting during normal operation. In addition, this site will have additional four motors added and this would have made the overall system very expensive and complicated.

MV soft starter

This alternative didn't reduce the motor start up current to satisfactory levels and thus did not comply with the supply authority's voltage drop requirements. Also this system introduced harmonics into the network during start up which also did not comply with the supply authority's regulations. It also proved to be a complex and expensive system overall.

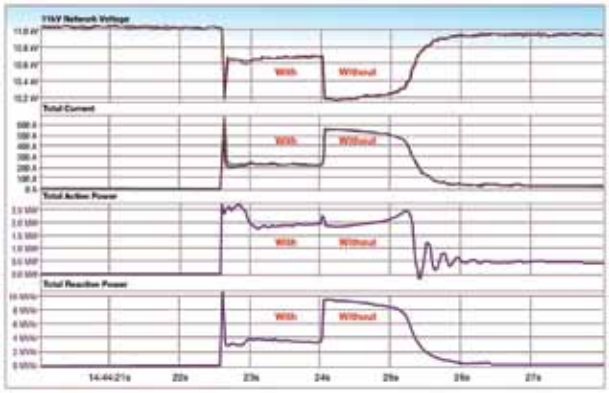

Figure 2: Motor start-up with and without compensation at 11 kV network voltage.

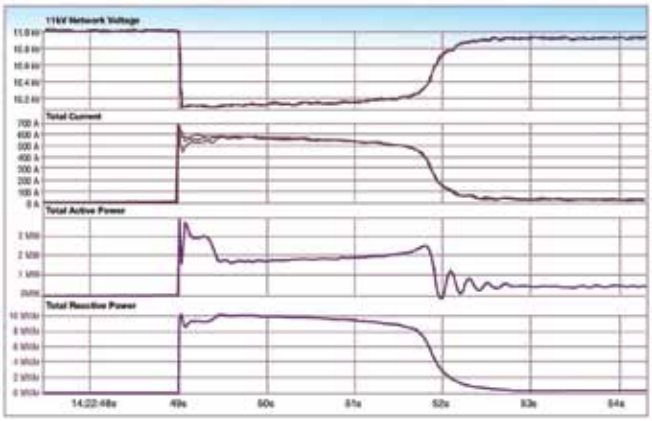

Figure 3: Motor start-up without compensation at 11 kV network voltage.

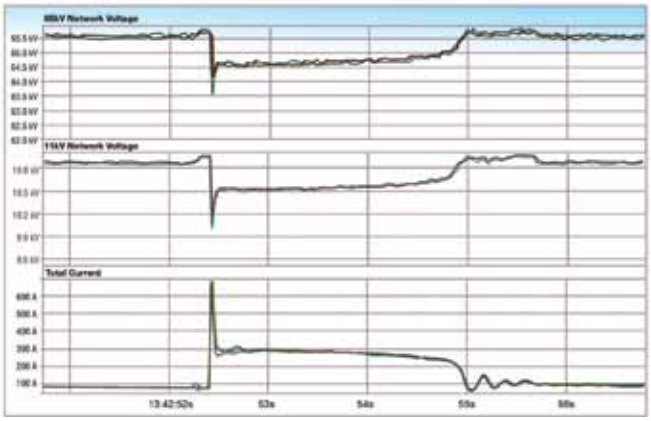

Figure 4: Motor start-up with Elspec EQ-ST only at 11 kV and 66 kV network voltage (66% compensation).

Fast switching reactive power motor starting

Due to the needs of meeting the supply authority regulations and costs and complexity associated with the other considered systems this is a perfect solution for multiple staged motor starting in this particular application. It uses simple components such as capacitors but switched using thyristors. The system relies on a very sophisticated controller which in fact is a network analyser that records all relevant parameters at up to 1 024 samples per 20 msec and so can react to changes in load within one voltage cycle (20 msec).

Conclusion

The use of ultra fast transient free switching power factor systems, that are capable of delivering complete compensation cycle by cycle in real-time, significantly reduces large voltage drops and high current peaks associated with motor starts. This technology has also proven to be more cost effective than traditional methods of using soft starters and VSDs for large motor start solutions.

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