DYNAMIC VAR COMPENSATION OF MINE HOISTS FOR IMPROVEMENT OF POWER QUALITY AND INCREASE OF PRODUCTIVITY AT LKAB SWEDEN

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ABSTRACT

The hoisting system in the iron ore mine at LKAB in Kiruna is a fast changing load that has been affecting the power quality of the electrical system for decades. In order to reduce the voltage variations and harmonic distortion to acceptable levels and at the same time increase production capacity a static var compensator (SVC) has been installed. The system design procedure and technical characteristics of the SVC have been previously described by us in Paper 0653 presented at CIRED 2009.
During the detailed design work special attention has been paid to the adjustment of harmonic filter tuning frequencies with regard to the long connection cable between the 6,3 kV indoor switchgear and the SVC yard. Besides, the special environmental and climatic conditions at LKAB in Kiruna have been taken into consideration when selecting air clearances and creepage distances of supporting insulators.
The installation and commissioning of the SVC has been completed by the end of october 2009. As a part of the commissioning tests, performance measurements have been carried out in order to verify that the SVC will fulfil the technical requirements specified in the contract.
The results of the measurements have shown that the contractual requirements regarding performance of the SVC are met or exceeded. It has been also verified that the ratings of the SVC and SVC components are correctly selected in order to withstand the fundamental- and harmonic load during the most severe operation conditions.
The service experience of more than 1 year operation is only positive. The voltage at the 145 kV PCC in Kiruna has been stabilized and the hoisting capacity at LKAB has been increased by approx. 30%

INTRODUCTION

In order to reduce the negative effects of the mine hoisting system at LKAB i Kiruna on the supplying network, a SVC has been installed with the purpose to compensate the fast power- and voltage variations caused by 7 thyristor driven DC drives. The SVC has a regulating range 0 - 35Mvar capacitive that allows simultaneous start of 4 motors when the remaining 3 motors are running at full speed resulting in stabilized network voltage and increased productivity.

This paper describes special design aspects that have been applied in order to ascertain reliable operation of the SVC. Further on, the results of performance tests are summarized and 1 years' service experience described.

INSTALLED SVC SOLUTION

The installed SVC solution is based on thyristor controlled reactors with 3 filter banks and a regulating range of 0 – 35 Mvar capacitive.
As the mine hoist drives are typical 6-pulse converters, with symmetrical load pattern and with characteristic harmonics of 5th, 7th, 11th, 13th, etc. the SVC configuration with filters for the 5:th, 7:th and the 12:th order as shown in the single line diagram (Figure1) was selected.

Critical design considerations

A critical issue was the right tuning for the filters, as the cable connection (about 250m) between the feeding switchgear and the SVC system represented an inductance, which had to be considered. Especially for the 12th harmonic high pass filter the dimensioning of the power cable, including the considerations for the laying of the cable, had to be done before the tuning of the filter could be calculated. For all three filters damping was applied to avoid the risk of resonance. The 5:th and 7:th harmonic filter damping was realized using Q-rings on the filter reactors as damping devices. The 12:th harmonic high pass filter was damped by using a damping resistor (Picture.1).

Picture 1. 12th harmonic filter with damping resistor

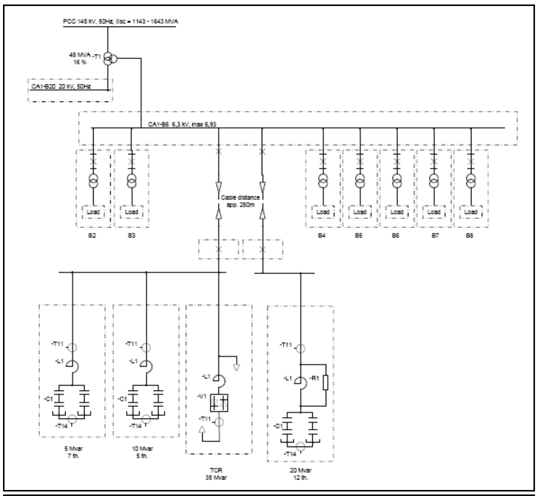
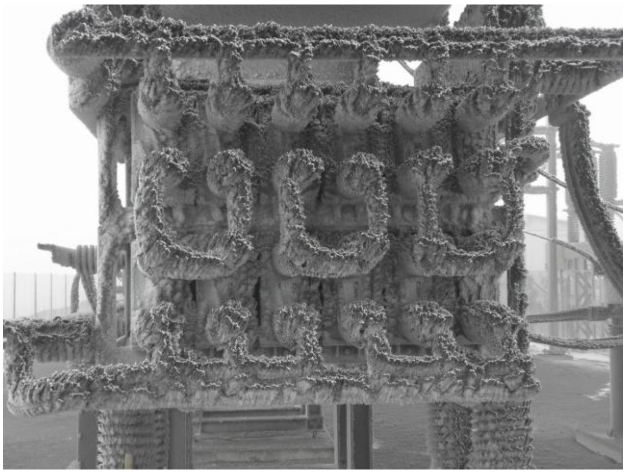


Figure 1. SVC, single-line diagram

Another critical issue was the environmental conditions as LKAB´s mine is north of the article circle. Special focus was given to clearance distances for all outdoor equipment, especially regarding iron ore dust and snow height. These considerations were of big importance. During the installation time in October 2009 an unexpected snowstorm showed the consequences of this rough climate. During this time the SVC was not in service, so the heat losses could not protect the filter banks from icing (Picture 2).



Picture 2. Climate conditions

PERFORMANCE MEASUREMENTS

As a part of the commissioning tests, performance measurements have been carried out in order to verify that the SVC will fulfil the technical requirements specified in the contract.

Measurement program

The measurements have been performed by means of high-resolution network analyzers and recorders connected to the 145 kV and 6,3 kV bus bars feeding the mine hoists and the SVC. The following values have been recorded:

- Flicker
- Voltage variations
- Active power, Reactive power, Power factor
- Harmonic voltage distortion
- Transformer Fundamental- and Harmonic currents
- Filer Fundamental- and Harmonic currents

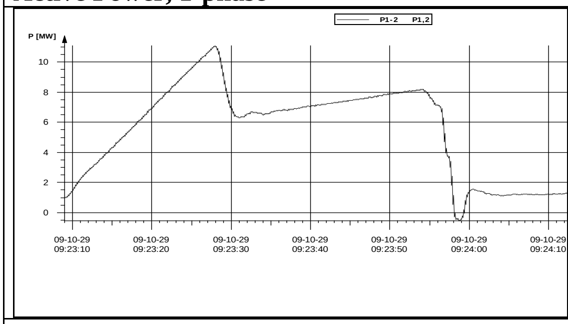
Operation conditions

The contractual performance requirements have been specified for operation condition when 3 hoists accelerate and 4 hoists run at maximum speed. Unfortunately, at the time of the measurements, one hoist was out of operation. For this reason, the operation of the hoist system has been programmed to allow 5 hoists to accelerate and one hoist to run at full speed simultaneously. In such way, operation conditions equivalent to the conditions specified in the contract have been obtained.

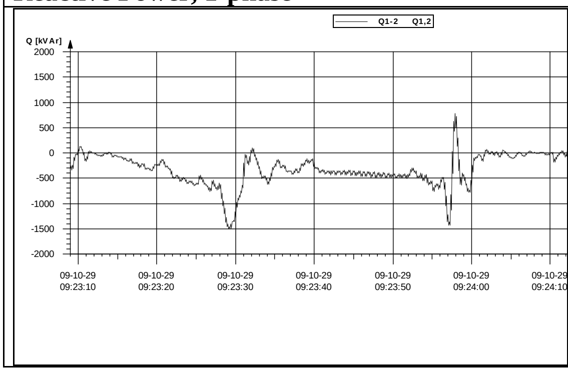
Results of measurements

Due to the space limitations of this paper, it is not possible to present all results of the measurements. For this reason only the most significant results are presented below:

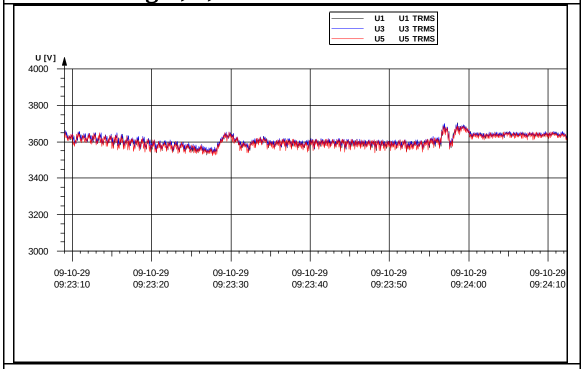
Active Power, 1-phase



Reactive Power, 1-phase



Phase-voltages, 6,3 kV busbar



Harmonic voltage distortion, 6,3 kV busbar

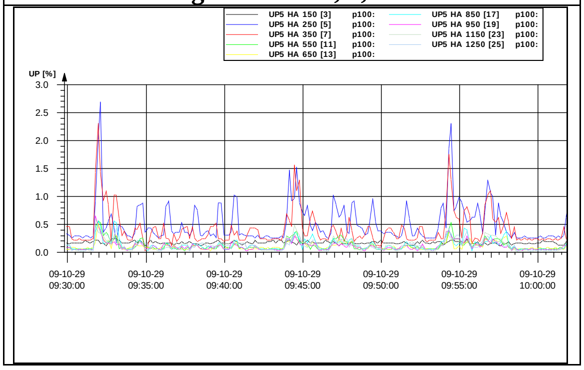


Figure 4. Results of measurements

The summary of the results of measurements and of the corresponding contractual requirements is presented in tables 1 and 2 below :

Parameter	**Limit**	**Result**
Flicker	1,0	0,9
Max. voltage variations	3%	3%
Power factor	0,98	0,998
Voltage distortion UTHD	4,8%	3,2%
Individual voltage distortion, odd harmonics	<60% of compatibility limits acc. to EN 50160	< Limit
Individual voltage distortion, even harmonics	<60% of compatibility limits acc. to EN 50160	< Limit
Total current distortion ITHD	5%	2%
Individual current distortion	3%	≤ 1,6 %

Table 1. Results'summary, 6,3 kV busbar

Parameter	**Limit**	**Result**
Flicker	1,0	0,3
Max. voltage variations	3%	1,3%
Power factor	n.a.	n.a.
Voltage distortion UTHD	1,5%	0,84%
Individual voltage distortion, odd harmonics	1,0%	≤0,75%
Individual voltage distortion, even harmonics	0,2%	≤0,06%
Total current distortion ITHD	5%	2%
Individual current distortion	3%	≤ 1,6 %

Table 2. Results'summary, 145 kV busbar

In addition to the measurements of the performance parameters, measurements of the fundamental- and harmonic currents in each filter branch have been performed. The results of the measurements have demonstrated that the rated filter currents exceed the measured values with large safety margins.

Conclusions from the performance measurements

The results of the measurements show that the supplier of the SVC has fulfilled his contractual obligation with respect to the performance of the SVC. It has been proved that all performance requirements have been met or exceeded. It has been also verified that the ratings of the SVC and SVC components are correctly selected in order to withstand the fundamental- and harmonic load during the most severe operation conditions.

OPERATING EXPERIENCES

The main goal of the installation of the SVC was to reduce voltage variations on the 6,3 kV and 145 kV bus bars. A comparison between the voltage variations on the 6,3 kV busbar without SVC and with SVC during normal operation at approx. 30 MW hoist load is shown in figures 5 and 6. It can be seen that the voltage variations have been typically reduced from +/- 10% to +/-2%. After more than one year of operating experience the plant has operated properly and we note that the hoisting capacity has increased by 25-30%.

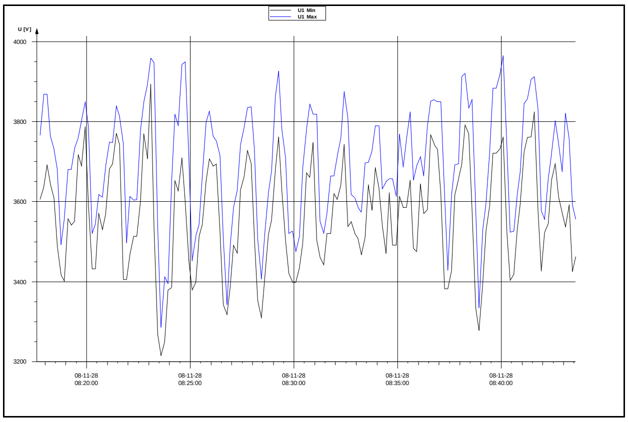


Figure 5. Voltage variations without SVC due to 29 MW hoist load

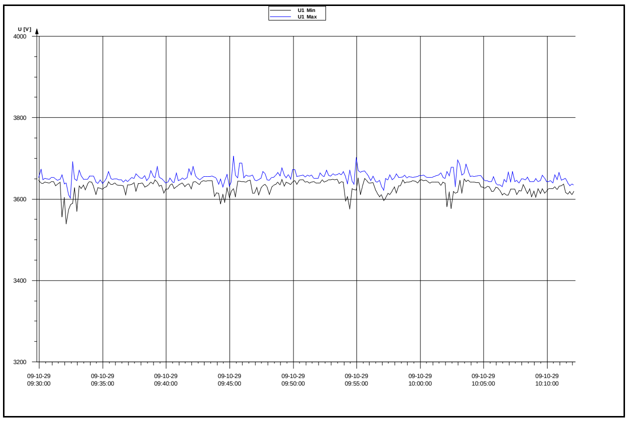


Figure 6. Voltage variations with SVC due to 33 MW hoist load

CONCLUSIONS

LKAB´s decision to invest in a dynamic reactive power compensation based on thyristor technology was the optimal decision in order to fulfill:

a) Utility power quality requirements
b) LKAB´s internal power quality requirements

The results of the verification measurements have shown that the SVC is meeting or exceeding the specified performance requirements and that the SVC components are adequately designed to withstand the most severe operating conditions.

This project proved that SVC solutions could provide power quality improvements for mine projects even in very tough environmental conditions.

Picture 3. LKAB SVC system

REFERENCES

[1] L Mukka, N Gothelf, C Payerl, 2009, " Dynamic var compensation of mine hoists for improvement of power quality and increase of productivity at LKAB Sweden", CIRED2009