POWER QUALITY SUPPORT FOR INDUSTRIAL LOAD USING HYBRID SVC

Jarmo AHO
Alstom Grid - Finland
jarmo.aho@alstom.com

Juha TURUNEN
Alstom Grid – Finland
juha.turunen@alstom.com

ABSTRACT

Dynamic power quality improvement and reactive power compensation are typically done either using SVC or STATCOM system depending on performance requirement. Installation and operational costs of a STATCOM are clearly higher compared to the costs of SVC. The benefit of using STATCOM is 2..3 times higher flicker reduction performance compared to SVC.

This paper describes a concept and real time simulation results of the concept, where SVC is combined with SVC to do the power quality improvement and reactive power compensation tasks. The target is to optimise the compensation system in terms of costs, performance and availability.

INTRODUCTION

Hybrid SVC is the working name of a concept where STATCOM and SVC are connected to the same network in order to co-operatively participate in the power quality maintaining at point of common coupling (PCC) – the typical measurement point for power quality of the electric grid. Flicker Pst is the most important quantity when evaluating the power quality at PCC. The measurement of flicker is defined in IEC standard 61000-4-15 [2]. Fig. 1 shows a simplified single line diagram of a hybrid SVC system.

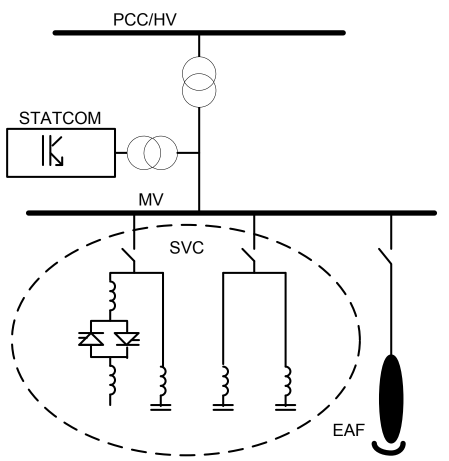

Fig. 1: Single line diagram of hybrid SVC with load

The SVC and STATCOM are connected to the same busbar, but cascaded from control point of view. SVC is compensating the reactive power of the load. Because of the moderate control speed of the thyristor valves included in the SVC, there is remaining reactive power fluctuation at PCC, which STATCOM is configured to compensate and to reduce harmonics.

SVC is typically capable to reduce the flicker caused by EAF load by a factor 2...2.5, while the flicker reduction factor of a STATCOM is above 6. By cascading the systems and using a reasonable relative power dimensioning between the systems a reduction factor 4..5 is reached fulfilling in most cases the power quality requirements defined by the grid operator. Off line (non real time) simulations have been made in the past by modelling the controllers, the hardware and the load [1]. This paper describes real time simulations using real FACTS controllers.

Performance measurements are made by creating a real time simulation model of a typical network, connecting SVC and STATCOM controllers to the simulator and running simulations using measured EAF current waveform data as load.

SVC is from operational point of view a functional system due to the limitations in speed of control. STATCOM with brand name SVC MaxSine® is described in earlier conference papers [3].

DOWN SCALING OF THE SIMULATION

The power rating of the simulated system was based on the following limitations:

1) The nominal power of STATCOM was rated 2 MVA, a nominal power of a single SVC MaxSine® unit.
2) The rated power of SVC was selected to be 10 MVA for reasonable dimensioning of interest: to reach good performance using STATCOM with small power rating

High flicker reduction requirements are related to weak networks and high load power. In practise it means that the EAF power rating is high (above 70 MW) and thus the reactive power compensation requirement is in the range of 100..200 Mvar to reach 100% compensation degree. Calculation of relative power ratings is done on project basis depending on e.g. the so called Kst value (severity factor) of the load. Impedances of the simulated down scaled network were calculated to match the lowered load power rating (7 MW).

STATCOM overload capability feature was in use in the simulations as the task of STATCOM is to compensate short term instantaneous fluctuations and mostly operating at partial power. From power optimising point of view it is important that the control of SVC takes into account upstream reactive power losses caused by the load.

SIGNALISATION OF THE SIMULATIONS

Fig.2 shows the signalisation between the RTDS simulator, controllers playback device and power quality analyser. The recorded data includes phase currents and one phase voltage, which is used to synchronise the simulated network with the phase angles of the load currents.

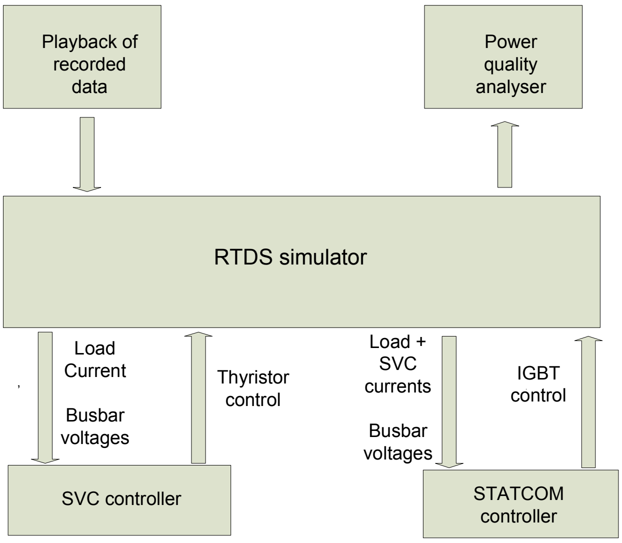

Fig. 2: Block diagram of the signalisation

SVC and STATCOM controllers receive voltage and current information from the simulated network to calculate the control signals for thyristor valve IGBT converter. Power quality analyser is used for evaluation of performance but also for tuning the controllers.

INTERFERENCE CONSIDERATIONS

There are two main possibilities to eliminate risk of interference between the compensation systems. First choice is to control STATCOM based on the sum of load and TCR currents. The second choice - used in the simulations - is to design the high voltage network so that the resonance frequencies seen from STATCOM connection and measurement point are shifted to minimum ±10 Hz distance from any harmonic frequencies. E.g. the 3rd HF resonance frequency is tuned to in the example (table 1) to 122 Hz. Since the load usually includes series reactors, the second choice can be used without affecting the behaviour of load. Table 1 shows an example of the tuning for a particular 150 Mvar rated SVC at 50 Hz grid. The resonance frequencies of the filter banks are tuned close to 2nd, 3rd and 4th harmonic frequencies. The last line "Tuned resonance frequency" shows the frequency seen from connection point of STATCOM. The of separation reactor inductance value 5 mH is by topology common for all re-tuned filterbank frequencies.

	2nd HF	3rd HF	4th HF
Power rating/Mvar	41,6	46	65,2
FB inductance/mH	31,2	11,02	4,1
Resonance freq./Hz	101	147	197
Separation ind./mH	5	5	5
Tuned res. freq./Hz	93,5	122	133

Table 1: Tuning of filter bank resonance frequencies

The inductance value of 2nd HF is dominant in defining the inductance value of separation reactor. Since the 2nd HF is typically a wide band filter, the dimensioning of the separation reactor depends on the impedance vs. frequency curve in surrounding of 2nd harmonic frequency. Fig. 3 illustrates the location of separation reactor related to STATCOM and SVC (patent pending).

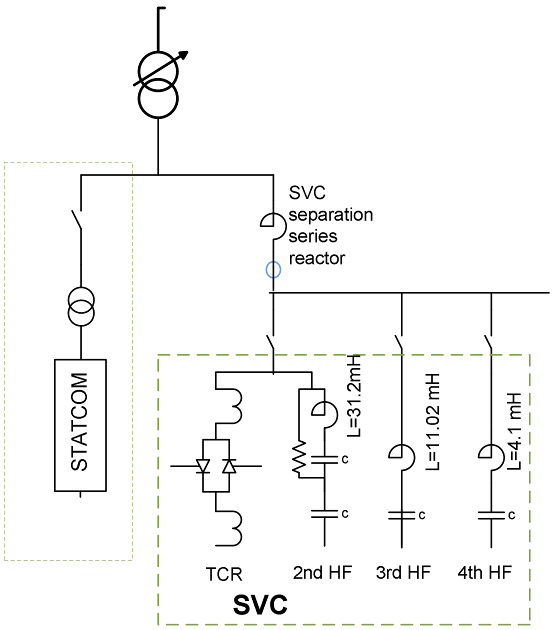

Fig. 3: Configuration of hybrid SVC system.

DIMENSIONING OF THE SYSTEM

SVC can be considered as slow active compensation device compared to STATCOM. SVC is not fully capable to respond to fast power fluctuations of the load. As a result, SVC is capable to reduce flicker by factor 2 which is not sufficient in many cases. The purpose of STATCOM as fast compensation device is to compensate the remaining reactive power fluctuation that SVC is not capable to handle.

The dimensioning of the complete system is optimal when required flicker reduction factor is reached while the STATCOM power is designed as low as possible. Obviously SVC has to be dimensioned for 100% compensation degree and controlled so that reactive power losses in the upstream reactive components are compensated so that the average reactive power at PCC is zero in a situation when STATCOM is disconnected.

The EAF load is characterised by severity factor Kst – a value that defines the amount of disturbances the EAF generates to the grid [4]. The reactive power fluctuation is increasing with the Kst value. Especially when the Kst value is high, it is essential that the STATCOM has short term overload capability feature. SVC is capable to respond to a change in the load within 20ms – a time required for full overload capability available of STATCOM.

A single MaxSine unit is rated 2 MVA. Typically required power rating is achieved by connecting 2 MVA units in parallel. Since a STATCOM (2MVA) unit requires lot of simulator hardware resources, it is not possible to model high power MaxSine as “as built” in the RTDS draft. Therefore the simulated load power was downscaled from 70 MW to 7 MW and the hybrid compensation system accordingly. Another choice would have been to upscale a single MaxSine converter model to a power rating in the range 20 MVA.

Fig. 4 shows the basic simulation model.

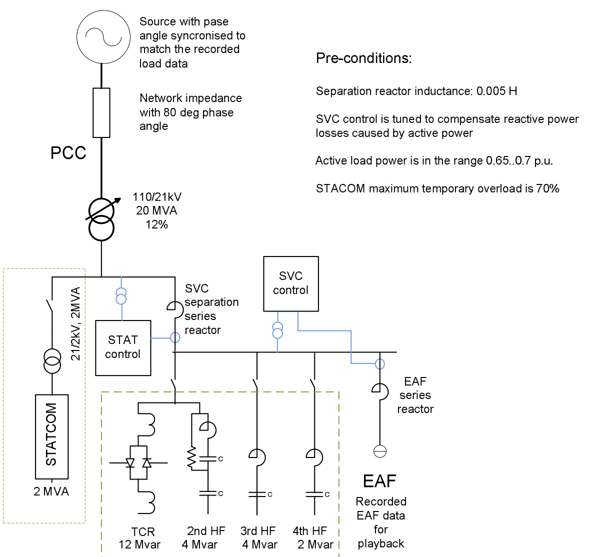

Fig. 4: Single line model of hybrid SVC system.

The STATCOM is rated for 2 MVA and with overload capability factor of 1.7 giving maximum instantaneous power 3.4 MVA. The total power of SVC filter banks is 10 Mvar. TCR is rated 12 Mvar to be capable to do load balancing. The selected relative power ratings between compensation devices is not optimized for particular case but is rather an average selection based on previous experience. The target in a practical case is to minimize the power rating of STATCOM. Increasing the size of STATCOM gives performance reserve and redundancy at the same time. The STATCOM is modular in 2 MVA steps.

SIMULATION RESULTS

Fig. 5 shows the active power of the load based on 10s averaging time. The yellow curve represents total active power.

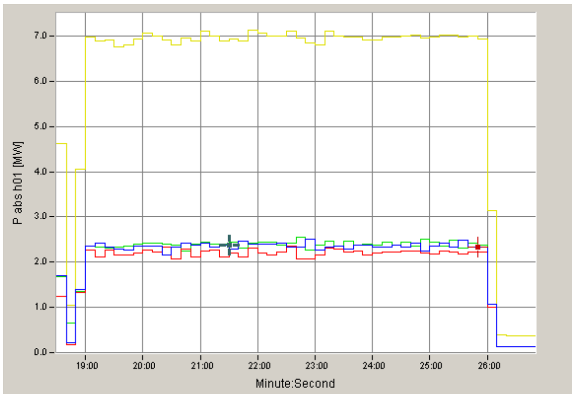

Fig. 5: Active power of the simulated load.

Fig 6 shows the non compensated reactive power during the same time window but using 200ms averaging time. STATCOM and TCR are switched off. Filter banks rated 6 Mvar were connected to keep the average reactive power close to zero. This is required to support the voltage in the situation without active compensation. The measurements of the non compensated case represent reference values – especially flicker - to which other simulations are compared.

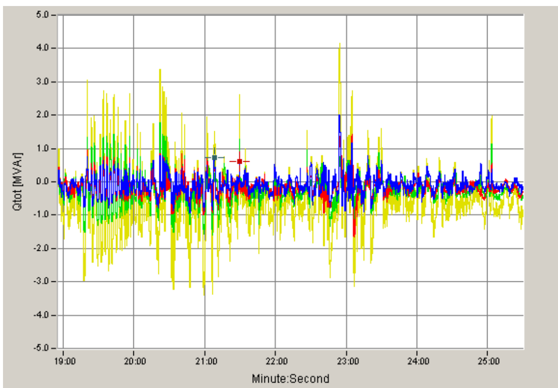

Fig. 6: Dynamic reactive power variation of the load

As is presented by a yellow curve in fig. 6, the reactive power variation range at PCC is -3…+4 Mvar, which means that the variation of the load reactive power is in the range +3…+10 Mvar. The instantaneous variation is even higher since the curves of fig. 6 are based on 200ms averaging times but even faster variations appear.

The simulated time window was 6 minutes. To obtain useful amount of measurement points for flicker mitigation evaluation and avoid errors related to starting points of evaluation periods, an averaging time 10 s was selected for the evaluation. Fig 7 shows per phase flicker values for compensated and non compensated cases.

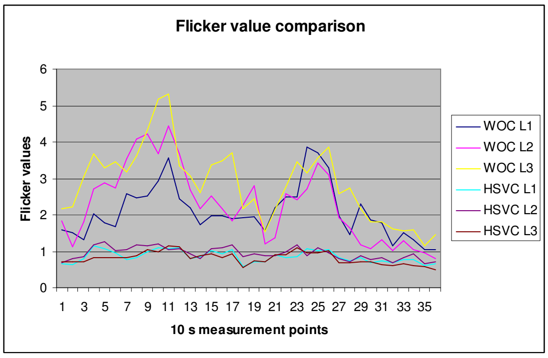

Fig. 7: Flicker values with and without active hyrid SVC compensation.

WOCL1/L2/L3 = flicker without compensation
HSVCL1/L2/L3=flicker w. active hybrid SVC comp.

As is shown in fig. 7, the compensated flicker values are low, regardless of the non compensated values. The result is visualised in fig. 8 by arranging non compensated flicker values in descending order.

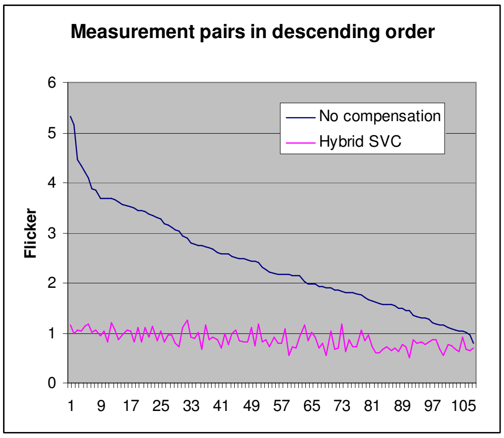

Fig. 8: All flicker values in descending order regarding non compensated flicker value.

The values representing operation with compensation (red curve) are slowly declining but can be considered as practically constant, almost independently from the blue curve representing operation without compensation. An almost fixed remaining flicker value of the compensated case leads to a conclusion that even higher flicker reduction values can be reached.

CONCLUSIONS

The results of the real time simulations using real compensation system controllers are verifying the results obtained in non real time simulations where flicker reduction factor 4.7 was verified using STATCOM power rated 0.25 PU compared to 0.2 PU of the real time simulation. It should also be emphasized that the results of the real time simulations are based on use of load current measurement from real EAF.

The achieved flicker reduction factors are encouraging, actually justifying the compensation system topology to be introduced and applied in cases where flicker reduction factor in the range 2.5…5 is required.

By additional optimising and applying the configuration on real environment the performance can even be improved compared to simulated results. A good performance combined with reduced installation cost and especially low losses makes the configuration attractive.

The need for maintenance of a STATCOM as complex system is higher than for SVC. In most cases the STATCOM can be taken occasionally out of operation for maintenance and continue with SVC in operation thus avoiding the interruption of EAF operation.

REFERENCES

[1] D. Michel. G. de Préville, 2004, "Mixed topology for flicker mitigation", *Proceedings Power Electronics, Machines and Drives*, 2004, Conf. publ. No. 498.

[2] "Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 15: Flickermeter – Functional and design specifications." IEC standard 2003.

[3] J. Aho, A. Syomushkin, R. Jessler, 2010, "Description and evaluation of 3-level VSC topology based STATCOM for fast compensation applications", *Proceedings ACDC,* 2010, Paper. No. 071.

[4] A. Baggini (ed.), Author, 2008, *Handbook of power quality,* John Wiley & sons, Ltd, Chichester, UK, 153.