APPLICATION OF HYBRID VAR COMPENSATOR FOR FLICKER CONTROL IN MESH WELDING APPLICATIONS

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ABSTRACT

Demand for voltage flicker mitigation in welding applications is becoming high. In this paper, a case study will present modelling of a Hybrid Var Compensator (HVC) to mitigate flicker in a mesh welding plant. Data captured from site is analysed, then used to derive a model for the welder. Simulation results are compared with site measurements to validate the model.HVC model is derived with simulation results used to determine levels of voltage flicker. Flicker indices are evaluated from voltage waveforms using methods addressed in IEC61000-3-7.Issues and guidelines related to modelling HVC are outlined and discussed. Simulation data will show significant improvement in P_{st} and P_{lt} levels.

INTRODUCTION

Small to Medium size welding plants are becoming more exposed to flicker problems. This can be contributed to increased demand for electricity, as well as high cost of network upgrade. Whilst flicker can be predicted and managed at the design stage, it is an unfortunate reality that the majority of the installations with major flicker problems are already operational. It is also common for these installations to have means of Power Factor Correction (PFC) solution in place. Where flicker is a problem, PFC equipment will have sufficient KVR capacity, but not capable of mitigating both flicker and Power factor (PF) due to its sluggish response. This will set a requirement for the flicker mitigation equipment to function with existing PFC equipment. This will help reduce system complexity and the size of the flicker mitigation equipment as well.

HYBRID VAR COMPENSATOR MAIN CHARACTERSITICS

HVC utilises Active Harmonic Filter (AHF) and PF capacitor banks to provide reactive current support where high speed inrush current causes significant voltage fluctuations. AHF will operate in Electronic Var Compensation (EVC) mode and must be capable of injecting leading or lagging current to regulate system's PF to near unity. In EVC mode, the AHF will have a steady state response of 20ms.

The PF capacitor banks may be capacitors only or detuned capacitors. The PF capacitor system may be existing or new. The AHF and PF capacitors maybe installed at separate locations as convenient on the electrical system (Figure 1).

The location of the Current Transformers (CT) is, however, critical. Since HVC system only injects reactive current, it will not be able to compensate for any voltage fluctuations caused by real power consumption. In cases where both real and reactive powers are significant, then it is possible to have HVC operating concurrently with cogeneration solution.

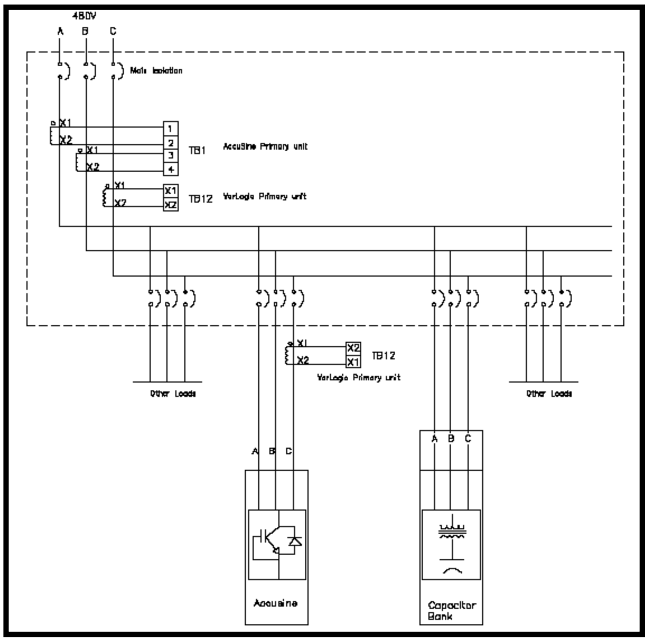

Figure 1: Typical installation of HVC system

CASE STUDY

Summary

The operators of a welding plant were approached by the utility to rectify severe levels of flicker indices reflected in to the network. Flicker measurements were carried out by both the utility and the operator. Flicker indices on HV and LV buses were way above the limits in IEC 61000-3-7 standard. The operators had limited options since the utility could not review the connection point capacity. The operator approached several entities to analyse and design a solution that will reduce flicker levels within the limits as per IEC 61000-3-7 standard.

Plant details

Supply

The site is supplied via 22KV feeder to on site 22kv/415v transformer rated at 750KVA, Z%=5.5%. The fault level at 22KV side is 4,123A with a Thevenin impedance values of

R1= 0.003 p.u. and X1= 0.00055p.u. for 100KVA base.

Load

Plant load includes the welding machine which contributes to the majority of the load, wire drawline machine and existing multi-step 1680 KVAR, SCR switched PF correction unit.

Welding Machine

Summary

The welding machine utilises nine welding transformers. Each three transformers are dedicated for one phase. The primary of each transformer is individually controlled by SCR controllers fed form the welding machine's control system.

Profile of the welding signal

A single welding action consists of ramp up period in 10 ms increments, then a hold period in 10 ms intervals where maximum current is achieved then a similar ramp down. Depending on the product line the ramp, hold time and load current will vary .In some product lines, a single weld can go up to 250ms with repetition every second for 52 seconds. The plant can produce welded mesh for 6 main diameters, with each diameter having a unique length and width.

Preliminary site measurements

For each product line with the PF controller in automatic mode, data were captured from site which included measurements for voltage, current, voltage-drop, KW, KVAR and KVA for single and complete welding cycle. Flicker indices were recorded using a flicker meter. The measurements were also repeated with PF controller disabled.

Preliminary analysis

Data was used to derive a model for the welder for each product line. The model was derived using ATP software. Simulation results were compared with site measurements to verify the accuracy of the model. Flicker indices were also evaluated from the simulated voltage waveforms using methods addressed in IEC 61000-3-7 then compared with site measurements. In order to achieve maximum accuracy, flicker indices were evaluated using method 1; PST= 1 curve for rectangular voltage changes [1]. The results were also confirmed from method 2; simplified assessment procedure for aperiodic voltage changes [1].Measurements taken with PFC OFF indicated the presence of significant voltage drop during a single weld. Careful analysis of KVAR, KW and KVA measurements showed that the voltage drop is due to real and reactive power. Voltage drop contributed from the reactive power is around 66% of the total voltage drop. Similar values of voltage drop were recorded with PFC ON. This had a strong indication that the PFC controller was not regulating PF during a welding cycle. In Figure 2, the voltage drop is substantial during a single weld which is consistent with the PFC controller not engaging enough steps to regulate the PF. After the weld cycle ends (load current drops), the PFC controller could not responded to load changes and capacitor steps were still engaged for 40ms causing a voltage rise. This voltage rise made the flicker values worse when compared with measurements while PFC was turned OFF. This trend is common across all product lines.

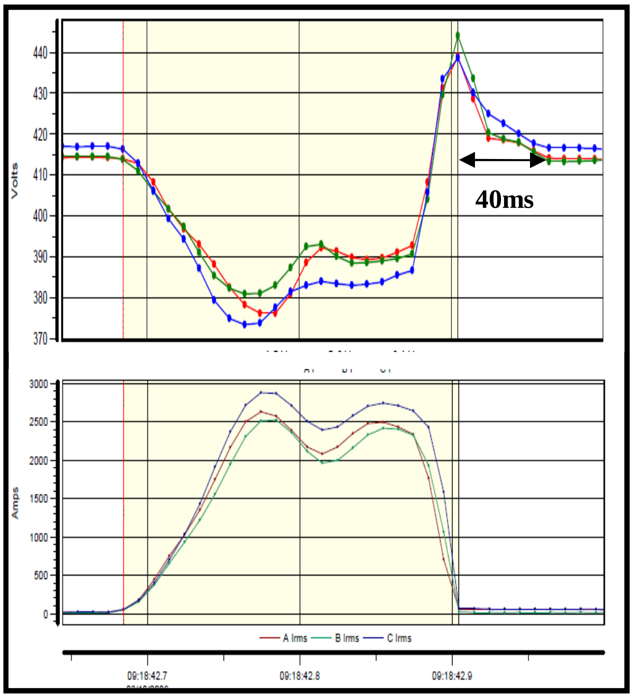

Figure 2: Bus voltage during a single weld with PFC ON

Secondary test

Aim:

- Determine the response time of the PFC controller.
- Identify electrical system's response with PFC equipment forced ON during a weld cycle.
- Indentify system's voltage drop at unity PF.

Description:

- Demonstrate system's voltage drop during a weld whilst PFC controller is forced ON.
- Record several measurements for voltage drop, PF, KVA, KW and KVAR.
- Eliminate the effect of PFC controller's response time on measurements.

Methodology:

- Manually engage capacitor banks in steps until 970 KVAR is achieved.
- Monitor system's voltage to reduce the risk of overvoltage trips.
- Apply several measurements for voltage drop, PF, KVA, KW and KVAR.
- Repeat the above test with PFC controller set to Automatic mode.

Analysis:

- Measurements applied with PFC in Automatic mode showed a voltage drop of 39.67V during single weld with system voltage of 425V.

- Recorded KVA, KW and KVAR are 1500, 1000, 1000 respectively.
- Measurements applied with PFC forced ON showed a voltage drop of 15 V during single weld when referred to system voltage of 425V (figure 4).
- Recorded KVA, KW and KVAR are 1028, 1000, 220 respectively.
- Voltage drop is mainly contributed to real power.

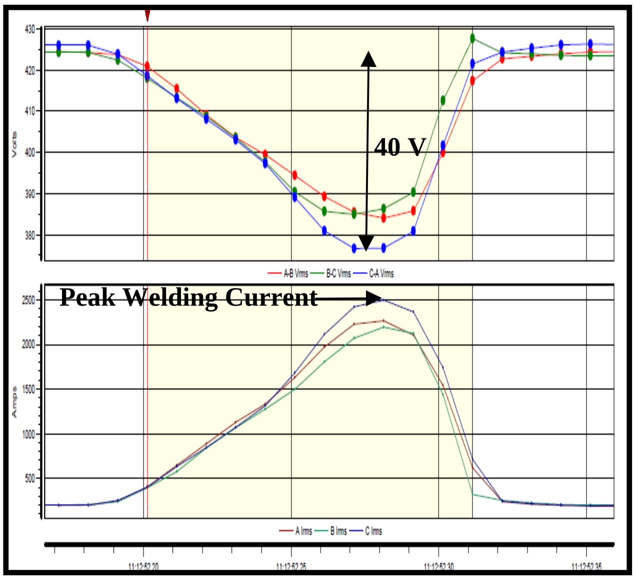

Figure 3: Voltage drop with PFC in Automatic mode

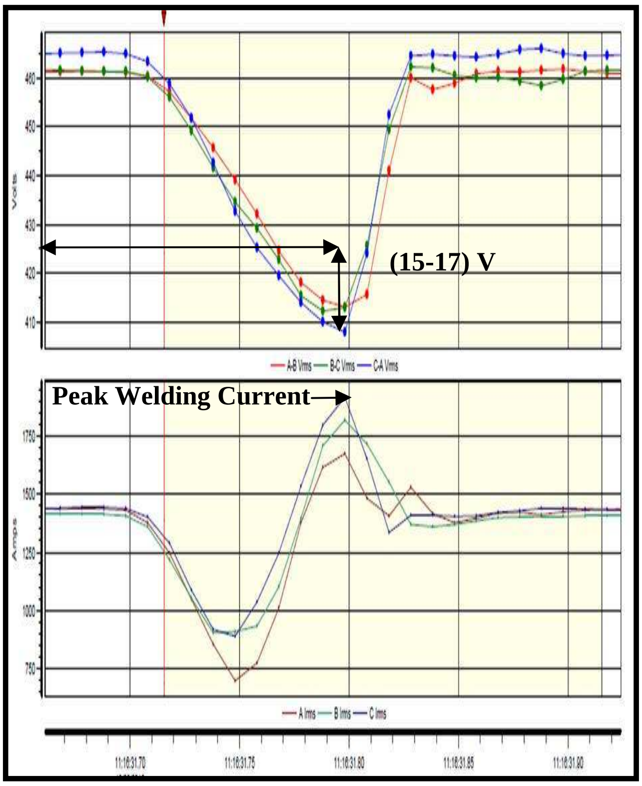

Figure 4: Voltage drop with PFC controller forced ON

Proposed solution

HVC will regulate system's reactive current during welding cycles. HVC will utilize AccuSine® Power Correction System (PCS) operating in EVC mode and existing PFC system (Figure 5).

PFC system:

- PFC will be fixed on the electrical system to support load without any delay.
- Logic system will be implemented to switch ON the steps in sequence prior to production. The steps maybe forced ON manually as an alternative.
- Logic system will be implemented to switch OFF the steps in sequence when production has ended.

AHF EVC:

- AHF will remain powered up and activated (in run mode) at all times.
- As load demand varies, AHF will adjust its output to maintain the mains reactive current equal to nil within the accuracy of the measuring CTs.

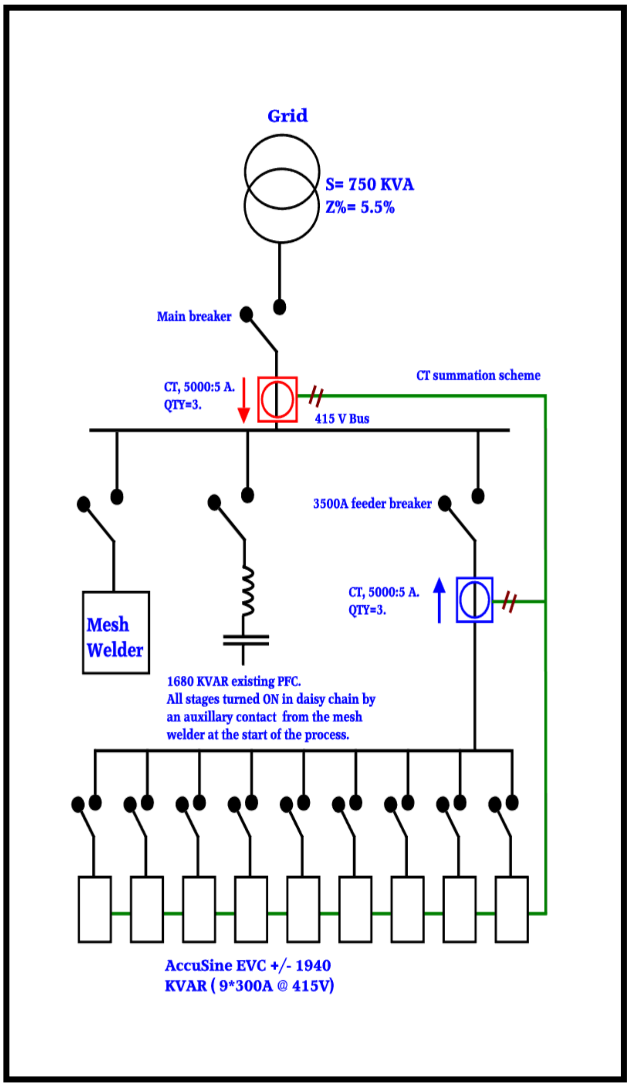

Figure 5: HVC layout utilising AccuSine® EVC &PFC

F82 sample results

HVC system OFF:

- Calculated P_{st} levels from simulation at the low voltage bus using methods 1& 2 are 12.77& 11.47 respectively.
- Levels of P_{st} measured at the low voltage bus are 12.5.
- Calculated P_{st} levels from simulation at 22KV bus using methods 1& 2 are 1.1& 0.98 respectively.
- Levels of P_{st} measured at 22KV bus are 1.2.

HVC system ON:

- Calculated P_{st} levels from simulation at the low voltage bus using methods 1& 2 are 4.1& 4.45 respectively.
- Calculated P_{st} levels from simulation at 22KV bus using methods 1& 2 are 0.351& 0.38 respectively.
- Figure 6 shows a decrease in system's voltage drop (ΔV) across the supply's impedance from 40-volts to near 20-volts when supply's reactive current is nil.

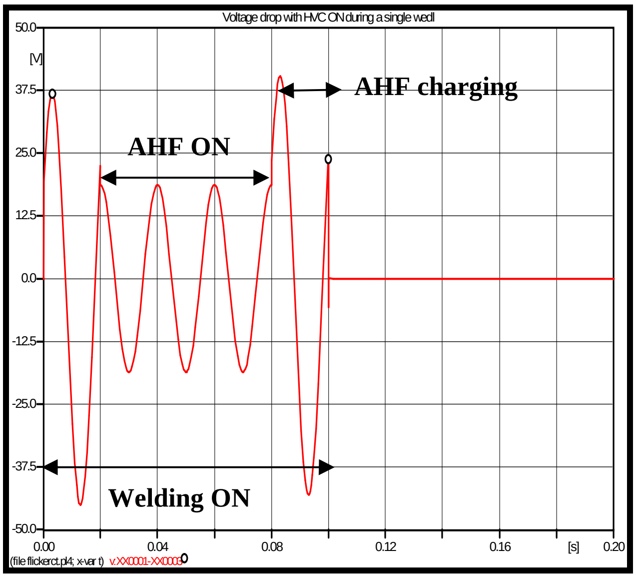

Figure 6: Simulated system ΔV when HVC is ON "PFC OFF"

METHOD TO MODEL ACCUSINE® (PCS) FOR HVC OPERATION

The method proposed will aid users to simulate the effect of HVC on ΔV during welding cycles. The model was prepared using ATP software. The process requires cycle by cycle measurements for KW& KVAR for each product profile. In this paper the mesh welder will be modeled as a resistor in parallel with an inductor. A specific model will have to be prepared for each product profile. HVC will be modeled as a current source in parallel with existing PFC. A key factor in deriving the model is the addition of delay in the response of the current source. This will provide accurate representation of ΔVduring a welding cycle. As a simple approach, the user may incorporate a delay function in the current source model.To allow for worst case scenario, HVC system has been modeled with an inherit delay response of 20ms. Consequently, the supply will support the load for a period not exceeding 20ms.Effect of HVC delay is shown in (Figure 6). For almost 20 ms, ΔV is maintained at 40-volts, then HVC becomes active and the voltage drop declines to near 17-volts. Main advantage of using the existing PFC system is to allow the AccuSine® Power Correction System (PCS) to charge its dc bus without incurring any voltage drops during welding cycles. Figure 7 shows ΔV during a welding cycle with PFC permanently turned ON. In this case, the PFC will support the load at all times with AccuSine® Power Correction System (PCS) maintaining PF at unity. The system response is enhanced, due to ΔV being kept low throughout the welding cycle. After the weld cycle is finished, AccuSine® will correct for the leading current from PFC. In (Figure 7),ΔV is maintained to near 17-volts throughout the welding cycle. After the cycle ends, AccuSine® is correcting leading PF from the permanently switched PFC for 3 cycles. AccuSine® will then need to charge its dc bus thus seizing its output for 20ms. During this period, ΔV across the supply internal impedance will rise to 40-volts. It is important to note that the bus will be capacitive.

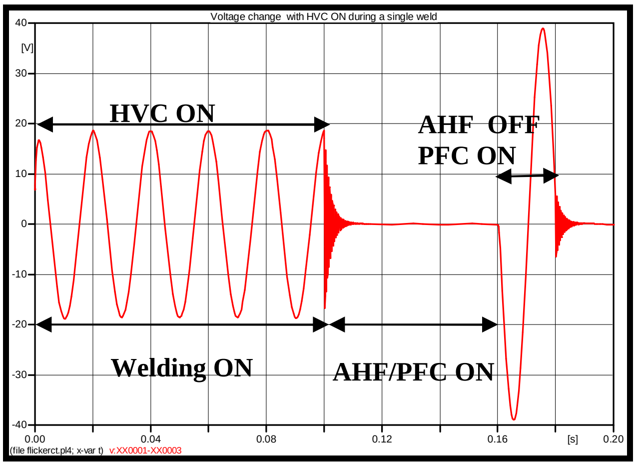

Figure 7: Simulated system ΔV when HVC is ON "PFC ON"

Conclusion

HVC can be utilized as a reliable solution for flicker mitigation. A simple guideline has been presented to help users model AccuSine® Power Correction System (PCS) to operate as HVC. A sample case has been documented with detailed analytical procedure and simulation results. Modeling & simulation was prepared using ATP software.

REFERENCES

[1] Assessment of emission limits for the connection of fluctuating load installations to MV, HV and EHV power systems, IEC61000-3-7:2007, ED.2/DTR.