Study Case

Active harmonic filters for data center loads

Achieving high power quality and reliability in today's energy-constrained world is a huge challenge. This is especially true for data centers. Power quality problems can set out within a fraction of a second and can cost millions of Euros in downtime. Data centers and other critical process facilities rely heavily on quality and reliability of power for their success. Data centers are facilities with a large number of IT equipment like servers and computers that have substantial power requirements and load factors of over 80%.

Data centers should ensure that uptime is maximized but they are highly susceptible to even the most common of power quality problems, a simple voltage sag can be as disastrous as a power interruption. Main consequences of low power quality in data centers:

- Revenue losses: Poor power quality and unreliable power supply can cause losses in terms of lost data, resources and productivity. The entire infrastructure and the equipment critical to the functioning of these facilities are also at risk.
- Failing customer service: Customer service is bound to go down with poor power quality and reliability. This ultimately brings down the level of customer satisfaction which in turn affects the client base of a particular facility.
- Service interruptions and downtime: Poor power quality and unexpected problems in data centers cause interruption in the smooth functioning of the facility and downtime as well.

1. Requirements

1.1. Background

The largest data center in Asia-Pacific located in South Korea that is the headquarters of several global IT companies was suffering from severe harmonic distortion. The total floor area of the data center is 85,548 m2 and the power capacity 165 MW/154 kV.

The owner of the building needed to secure the operations and eliminate harmonic distortions in order to maintain the quality and integrity of the businesses. The target of this project is to improve the operation of the data center by reducing the harmonic distortion to comply with THDi under 5%.

1.2. System description

The electric power system of the data center could be described as per below diagram.

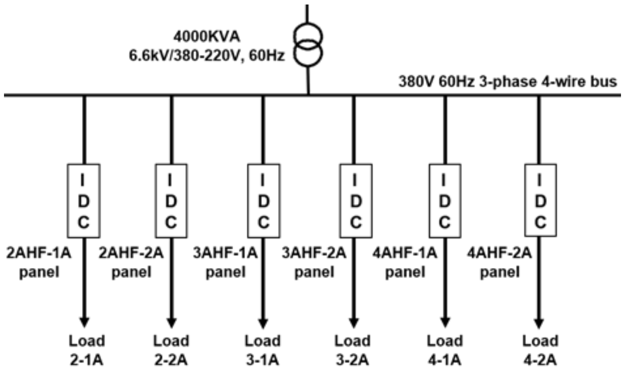

Figure 1 Data center electric power system

1.3. Challenges

The harmonic distortions were caused by the data center loads, mainly the double conversion static UPS systems (average power 10 kW), computers and LED lamps.

To be able to dimension a solution it was necessary to collect power quality measurement data from the six different switchboard panels of the data center over a period of time by using a power quality analyser.

2. Solution

2.1. Analysis of measurements

An extensive power quality analysis was done for the complete installation. Based on the data from measurements it was clear that an active solution was required to fix the power quality problems. It was decided to install power quality improvement solutions in the six different switchboard panels.

As an example, the existing power quality parameters at the panel 2AHF-2A before compensation were:

- Power factor: 0.82 (ind.).
- Average current: 83.12 A.
- Average voltage: 394 VAC.
- THDi: 59.6%.

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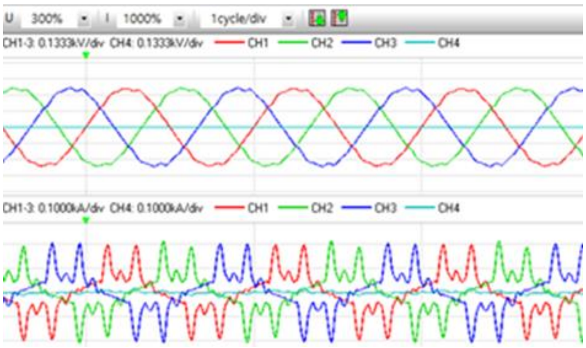

Figure 2 Existing voltage & current waveforms at 2AHF-2A panel

2.2. Proposed solution

Based on the analysis of the measurements, it was possible to dimension a solution for the data center that would comply with customer's requirements of reducing the amount of harmonics of the whole installation to be able to comply with THDi under 5%. It was decided to use six different active harmonic filters (AHF) installed on each switchboard panel of the data center.

Panel	Location	Device
2AHF-1A	Floor 2 server room TPS	AHF 380V 60Hz 100A
2AHF-2A	Floor 2 server room TPS	AHF 380V 60Hz 100A
3AHF-1A	Floor 3 server room TPS	AHF 380V 60Hz 100A
3AHF-2A	Floor 3 server room TPS	AHF 380V 60Hz 100A
4AHF-1A	Floor 4 server room TPS	AHF 380V 60Hz 100A
4AHF-2A	Floor 4 server room TPS	AHF 380V 60Hz 100A

Table 1 Proposed solution

Because of the nature of the loads and the application, and the need for real-time harmonic filtering, using conventional solutions like passive harmonic filters or capacitor banks was not an option.

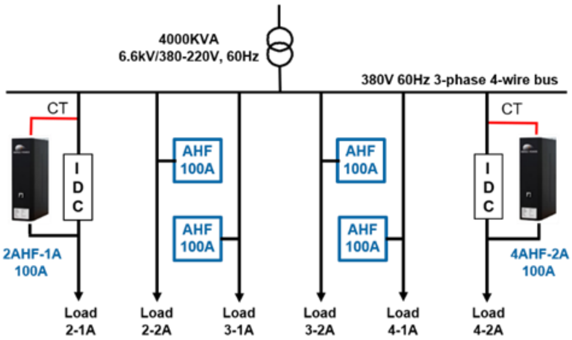

Figure 3 Proposed solution

2.3. Key features

Active harmonic filters (AHF) are the ultimate answer to power quality problems and grid code requirements for a wide range of segments and applications. They are a high performance, flexible, compact, modular and cost-effective type of active power filters (APF) that provide an instantaneous and effective response in low or high voltage electric power systems. They enable longer equipment lifetime, higher process reliability, improved power system capacity and stability, and reduced energy losses, complying with most demanding power quality standards and grid codes.

Figure 4 AHF module rated 380V 50/60Hz 100A

AHFs eliminate waveform distortions from the loads like harmonics, interharmonics and notching, by injecting in real-time in the electric power system the distorted current of same magnitude but opposite in phase. They can also work as harmonic generators for harmonic injection testing purposes. In addition, AHFs can take care of several other power quality problems and grid ancillary services by combining different functions in a single device. Some of them are:

- Elimination of harmonics and interharmonics.
- Power factor correction (lagging and leading).
- Reduction of voltage variations (sags & swells).
- Mitigation of voltage fluctuations (flicker).
- Load balancing in three-phase systems.
- Controlled and selectable harmonic generation.

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3. Results

3.1. System configuration

Six AHFs were installed at the switchboard panels of the data center, one on each panel, two per floor.

Figure 5 AHFs at the server room in the second floor

Figure 6 AHF 380V 60Hz 100A located at 2AHF-2A panel

The HMI of the AHFs was used to select the different operation parameters and monitor power quality parameters such as current, voltage and power waveforms from both network and load side.

Figure 7 HMI showing voltages at 2AHF-2A panel

Based on the values monitored it was decided to use the following settings on the AHF located at at 2AHF-2A panel.

Power factor	Target 0.98 (ind.).
Voltage fluctuations	Flicker mitigation was not necessary.
Load balancing	Reduction of unbalance between line currents to under 5%.

Table 2: SVG's functions used

3.2. Measurements

The system was monitored with an external power quality analyser to validate the operation of the AHFs. The trend charts (recorded with one second intervals) were taken with the AHFs connected and disconnected. Below measurements are coming from panel 2AHF-2A where an AHF 380V 60Hz 100A was installed.

Figure 8 THDi at panel 2AHF-2A reduced from 59.60% to 17.36%

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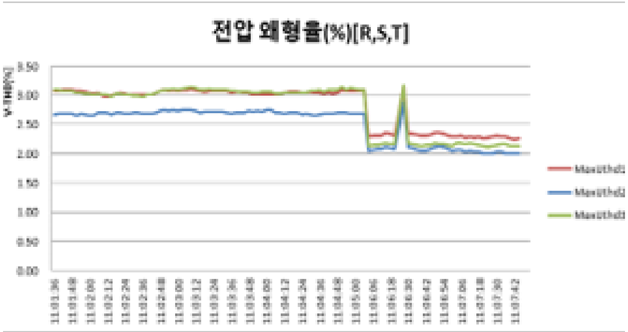

Figure 9 THDv at panel 2AHF-2A reduced by 16%

Figure 10 Load current at panel 2AHF-2A reduced from 83.12 A to 74.58 A

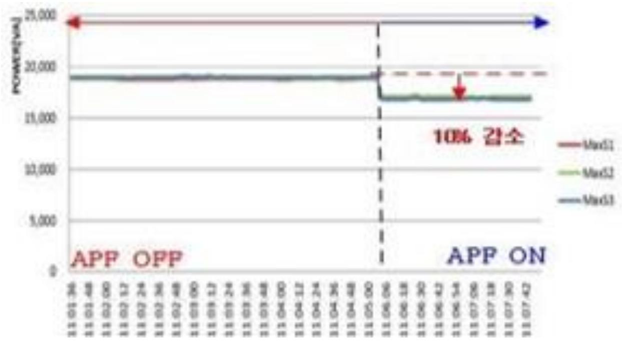

Figure 11 Apparent power at panel 2AHF-2A reduced 10% from 18.9 kVA to 17 kVA

Figure 12 Reactive power at panel 2AHF-2A reduced 43% from 10.8 kvar to 6.1 kvar

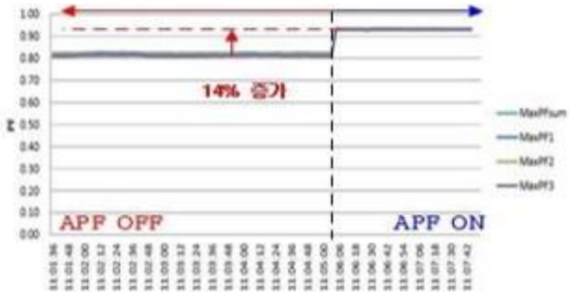

Figure 13 Power factor at panel 2AHF-2A improved from 0.82 to 0.93

	Currents distortion (%)			Currents (A)		
	AHF OFF	AHF ON	Rate (%)	AHF OFF	AHF ON	Rate (%)
2nd	0.27	0.38	41.37	0.18	0.26	47.81
3rd	1.10	1.36	23.37	0.72	0.94	29.22
4th	0.31	1.00	221.22	0.21	0.69	235.12
5th	34.48	6.52	-81.09	22.68	4.49	-80.22
6th	0.58	0.83	42.25	0.38	0.57	48.52
7th	28.41	2.85	-89.98	18.69	1.96	-89.51
8th	0.63	0.90	43.06	0.41	0.62	49.65
9th	3.74	2.34	-37.35	2.46	1.61	-34.53
10th	0.40	1.04	160.52	0.26	0.71	172.19
11th	28.58	4.99	-82.54	18.79	3.43	-81.73
12th	0.53	0.80	50.72	0.35	0.55	57.67
13th	24.10	4.15	-82.79	15.86	2.86	-81.99
14th	0.41	0.49	19.26	0.27	0.34	24.64
15th	3.54	4.09	15.36	2.25	2.65	17.55

Table 3: Harmonic currents and distortion at panel 2AHF-2A

3.3. Benefits

The installation of the AHFs reduced the harmonics in the data center bringing several benefits:

- Harmonics THDi reduced from 20% to below 5%.
- Power factor improved from 0.82 to 0.99 achieving a reduction in kVA maximum demand, in losses and in the electricity bill.
- All loads are balanced in the building, unbalance is less than 10%.
- Electrical equipment lifetime increased.
- Load current reduced.
- Capacities increased for power cables and power devices.

4. Conclusions

Rise of nonlinear and other challenging loads in electric power systems present unique power quality challenges. Active power filters like AHFs provide a quick and effective response to power system disturbances enabling longer equipment life, higher process reliability and reduced energy losses, complying with most demanding power quality standards and grid codes.

Data centers have evolved to become large power consumers. Their supporting infrastructure, such as cooling and power distribution, consumes big quantities of. electric power, and their IT equipment generates power quality problems that affect the secure and reliable operation of data centers. Therefore, the power quality and efficiency of data centers are important topics that should be addressed carefully at design stage or during the operation stage.

Country	South Korea
Segment	Critical process facilities
Application	Data center loads (double conversion static UPS systems, computers and LED lamps)
Requirements	Harmonics mitigation to comply with THDi under 5%.
Solution	6 units of AHF 380V 60Hz 100A
Commissioning	2018

Table 4 Project summary

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