EVS27
Barcelona, Spain, November 17-20, 2013

Power Quality Analysis and Harmonic Suppression of High Latitude and High Alpine Region Electric Vehicles Charging Station

Wu Guoliang, Xu Bingliang,Yu Haiyang, Dong Erjia
Heilongjiang Electric Power Research Institute,
XiangJiang Road No.7 , XiangFang District, Harbin, Heilongjiang Province, China
wuguolianghit@gmail.com

Abstract

In China, the first electric vehicles charging station of high latitude and high alpine region was built in Heilongjiang Electric Power Research Institute. In this research, electric vehicles charging station was introduced including a 100 kW DC charger and the main circuit diagram of EV charging station. In order to improve power quality and suppress harmonic, a shunt active power filter was applied in the EV charging station. To verify the effect of the shunt active power filter, charging experiments under different current for a bus were undertaken.

Keywords: Power quality Analysis，Harmonic Suppression，High Latitude and High Alpine Region，Charging Station

1 Introduction

Heilongjiang province lies on northeast China and it is in the high latitude and high alpine Region. In order to develop electric vehicles in Heilongjiang province, Heilongjiang Electric Power Research Institute built the first high latitude and high alpine electric vehicles charging station in China.

As far as electricity load of power system, electric vehicle charger is a kind of harmonic source load [1-3]. The harmonic current injects into the power system during AC-DC converting process, which affects power quality. Power electronics device injects a lot of harmonic and sub-harmonic, which leads the AC grid voltage and current waveform distortion [4, 5]. When electric vehicle charger works, the power factor of AC grid decreases. Electric vehicles charger becomes the most important source of harmonics. Therefore, it is necessary to control harmonic and improve the power factor.

In order to decrease the effect of Electric vehicles charging to grid, Heilongjiang Electric Power Research Institute set up an Active Power Filter to decrease harmonic current.

2 High latitude and high alpine region electric vehicles charging station

The charging station is composed of power supply system, charging system, monitoring and controlling system and active power filter system.
Power supply system serves for charging equipment, monitoring system, lights in the charging and discharging station.
On the one hand, power supply system, provides power to the entire EV charging station. On the other hand, it provides power to EV charger and AC charging piles. The charging system is the core

of the EV charging station, including EV charger and AC charging piles. Charging station has a 100 kW DC charger for electric buses and a AC charging pile for electric cars. In order to improve power quality and decrease harmonic current, the charging station has an active power filter for harmonic control.

2.1 The 100 kW DC charger

The input voltage of the charger is 380V and the power frequency of the charger is 50Hz. The charger topology is a three-phase bridge rectifier circuit. The alternating current is converted to direct current by a three-phase bridge rectifier circuit. The out rated voltage of the charger is 500V and the out rated current of the charger is 200A. The theory diagram of DC Charger is shown in Figure 1.

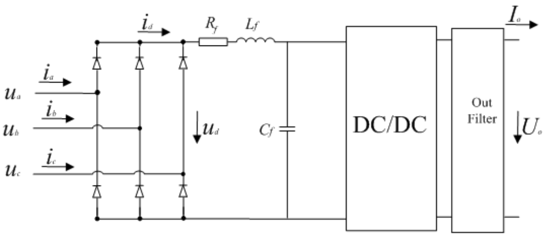

Figure 1: The theory diagram of DC Charger

3 Main circuit diagram of EV charging station

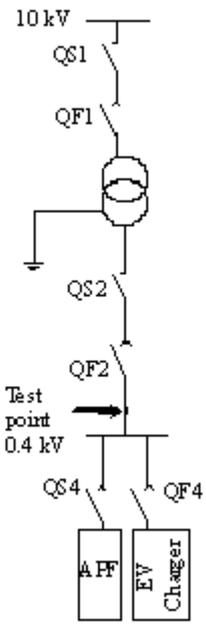

Figure 2: Main circuit diagram of EV charging station

The Main circuit diagram of EV charging station in shown in Figure 2. A 100 kW DC charger is used to charge electric vehicles. A 100 kVA Shunt Active Power filter is equipped with the EV charging station to suppress the harmonic current generated when the electric vehicles are charging.

4 The shunt active power filter of EV charging station

Overall, the series active power filter compensates voltage harmonic and eliminates system imbalance. It also adjusts voltage fluctuations and flicker and improves the distribution network stability or damping oscillation. The shunt active power filter compensates current harmonics and reactive power.

Current harmonic is the main harmonic source of electric vehicle charging station. As shunt active power filter is good at suppressing current harmonics, in addition, it is easier to implement and cheaper than hybrid active power filter, a shunt active power filter is applied in EV charging station.

The shunt active power filter is three-phase three-wire connection. The power is 100kVA,The operating voltage is AC 0.38kV. The operating frequency is 50Hz and filter range is from 2 to 25 harmonics. The parameters of APF is shown in Table 1.

Table 1: Parameters of the Shunt Active Power Filter

Parameters	Value
Operating Voltage（kV）	AC 0.38±10%
Operating Frequency（Hz）	50±5%
System Connecting Pattern	Three-phase three-wire system
Range of Filter	2～25 harmonic
Power Electronic device	IGBT
Corresponding Time	＜20ms
Environment Temperature	-10℃～40℃
Cooling Method	Wind

5 Harmonic test and power quality analysis

In order to analyze the effect of EV charging to AC grid, a harmonic test is undertaken in the charging and discharging experiment. In addition, compare the data before and after the active power filter working to analyze the advantage of active power filter for harmonic control. During the process of test, DC charger charged the EV bus with 40A. The input signal of power quality tester is the secondary current of the line current transformer to measure the harmonic current before and after the active power filter working. The test point is shown in Figure 2.

The measured results show that the main sub-harmonics and power factor has improved significantly after the active power filter switching on 380V bus. A comparison of harmonic and power factor of the of 380V bus between before and after the active power filter operating, which is shown in Table 2.

The equipment of the Harmonic test and Power quality Analysis was HIKIO8860, which recorded the harmonic and analyzed the power quality.

Table 2: Comparison of harmonic and power factor of the grid before and after the active power filter operating

Phase A	5th Harmonic/A	7th Harmonic/A	11th Harmonic/A	13th Harmonic/A	Power factor
Before APF operating	21.93	14.67	4.36	3.27	0.75
After APF operating	6.12	5.05	2.89	2.16	0.93
Improved Effect/%	72.09	65.58	33.72	33.95	18

Power factor curve of phase A is shown in Figure 3. Power factor curve of phase A is 0.75 before APF operating and it is 0.75 after APF operating, which means power factor improves 18%.

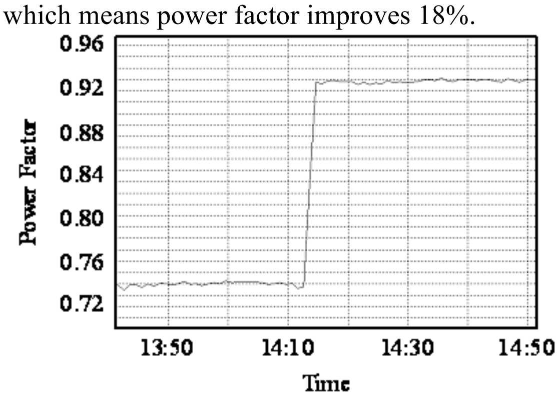

Figure 3: Power factor curve of phase A

The 5th, 7th, 11th and 13th order harmonic currents of phase A are shown from Figure 4 to Figure 7. APF operated at 14:15 PM. The 5th order harmonic current of phase A reduces 15.81 A, which means it reduces 33.7%. The 7th order harmonic current of phase A reduces 9.62 A, which means it reduces 65.6%. The 11th order harmonic current of phase A reduces 1.47 A, which means it reduces 33.7%. The 13th order harmonic current of phase A reduces 1.11 A, which means it reduces 33.95%.

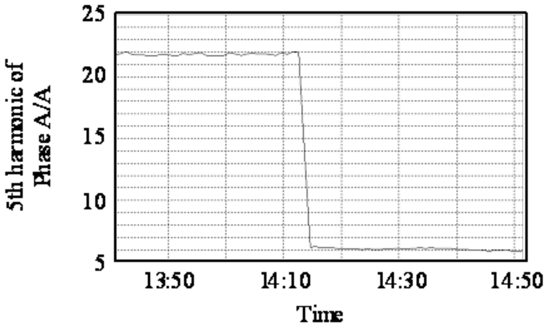

Figure 4: The 5th order harmonic current of phase A

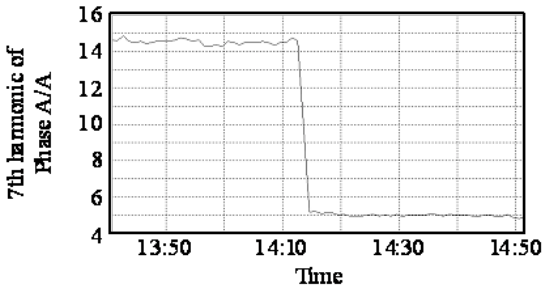

Figure 5: The 7th order harmonic current of phase A

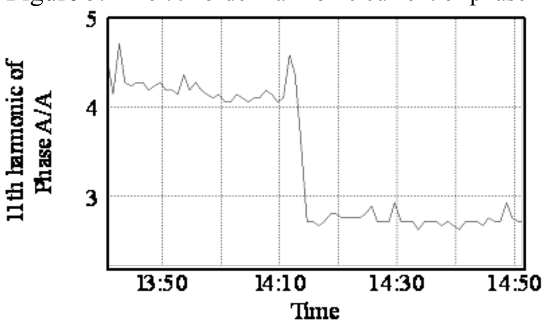

Figure 6: The 11th order harmonic current of phase A

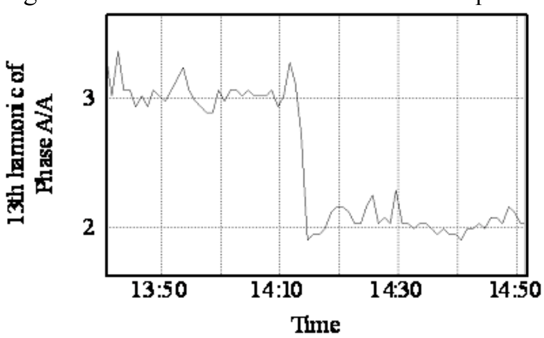

Figure 7: The 13th order harmonic current of phase A

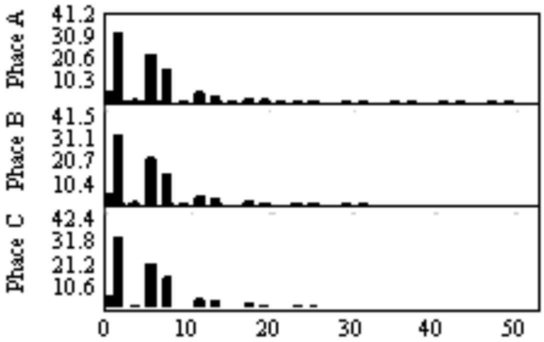

Figure 8: Current spectrum of A-phase, B-phase, C-phase of 380 V bus of charging station before the active power filter in operation

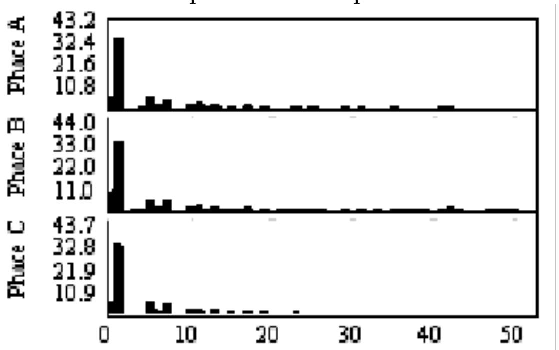

Figure 9: Current spectrum of A-phase, B-phase, C-phase of 380 V bus of charging station after the active power filter in operation

Current spectrum of A-phase, B-phase, C-phase of 380 V bus of charging station before the active power filter in operation is shown in Figure 8. Current spectrum of A-phase, B-phase, C-phase of 380 V bus of charging station before the active power filter in operation is shown in Figure 9. Table 3 and Table 4 show the experiment results of charging current under 50A and 100A.

Table 3: Comparison of harmonic of the grid before and after the active power filter operating under 50A charging current

Phase A	5th Harmonic/A	7th Harmonic/A	11th Harmonic/A	13th Harmonic /A
Before APF operating	21.71	14.05	3.24	2.80
After APF operating	4.81	4.11	1.89	1.57
Improved Effect/%	77.84	70.75	41.67	43.93

Table 4: Comparison of harmonic of the grid before and after the active power filter operating under 100A charging current

Phase A	5th Harmonic /A	7th Harmonic /A	11th Harmonic /A	13th Harmonic /A
Before APF operating	34.59	19.26	4.82	4.09
After APF operating	7.86	6.86	2.96	2.83
Improved Effect/%	77.28	64.38	38.59	30.81

The 5th, 7th, 11th and 13th order harmonic currents of A-phase, B-phase, C-phase decreases obviously. The active power filter inputs play a good role in harmonic control.

6 Conclusions

The electric vehicle charging experimental results show that, after the operation of the active power filter, main sub-harmonics of A-phase, B-phase, C-phase of 380 V bus had been significantly decreased and power factor of A-phase, B-phase, C-phase of 380 V bus had been improved. Five conclusions are shown below.

1) 5th harmonic of A-phase decreased 72 % at least.

2) 7th harmonic of A-phase decreased 64.38% at least.

3) 11th harmonic of A-phase decreased 33.7% at least.

4) 13th harmonic decreased 30.81% at least.

5) A-phase power factor increased from 0.75 before active power filter operating to 0.93 after active power filter operating. The power factor improved 18%.

6) 5th, 7th, 11th and 13th harmonic of A-phase, B-phase and C-phase decreased obviously when active power filter operated.

As active power filter operation of electric vehicle charging and discharging station of Heilongjiang Electric Power Research Institute, the harmonic are inhibited and power factor improved significantly.

7 References

[1] Huang Shaofang, Research on harmonic of electric vehicles chargers[D], Beijing Jiaotong University,2008(in Chinese)

[2] Yin Chunjie, Zhang Qian, Liu Zhen, Zhang Chenghui, The scheme of reactive

compensation and harmonic suppression for the power supply system of electric vehicle charging station[J], Power Electronics, 2011, 45(12): 63-65(in Chinese).

[3] Huang Mei, Huang Shaofang, Jiang Jiuchun, Harmonic study of electric vehicles chargers [J], Journal of Beijing Jiaotong University,2008, 32(5): 85-88 (in Chinese).

[4] Liu Yin, Research on harmonic current detecting method and control system of active power filter[D], Nanjing, Jiangsu University, 2010(in Chinese)

[5] Zheng na, A study of the influence of active power filter on load[D], Beijing, Beijing Jiaotong University, 2010(in Chinese)

Authors

Wu Guoliang, PHD, he works at Heilongjiang Electric Power Research Institute. In 2010, he achieved PHD degree in Harbin Institute of Technology. His research fields are Charging and Swapping technology of Electric vehicles, Smart Grid, and Battery storage technology. In addition, he was a member of promotion network in IEEE VPPC 2010 (France). He also was a member of national organizing committee in IEEE VPPC 2008 (China).
E-mail: wuguolianghit@gmail.com.