POWER QUALITY MANAGEMENT EXPERT

RXPE
RONGXIN 荣信

SVG

RXPE STATIC VAR GENERATOR

Liaoning Rongxin Xingye Power Technology Co.,Ltd.

version **R25.04**

www.rxpe.com/en

Create A Green / Intelligent / Efficient Power World

LIAONING RONGXIN XINGYE POWER TECHNOLOGY CO.,LTD.

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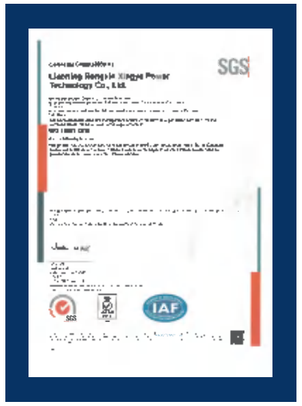
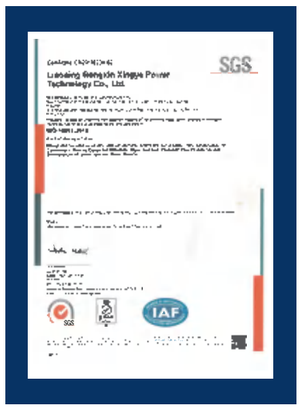


Company introduction

Cooperation and Innovation

Liaoning Rongxin Xingye Power Technology Co., Ltd. is a key high and new-tech enterprise of China, which is mainly engaged in the R&D, design and manufacturing of high-power electronic equipment. The whole line of products can meet the application requirements from power generation, power transmission and power distribution to terminal load, and provide comprehensive solutions to improving power quality, optimizing control and energy saving for customers.

As an important branch of reactive power compensation, SVG owns many advantages such as fast response speed, stronger grid voltage stabilizing capability, wider operating area for transmission capability and transient voltage limit improvement, lower harmonics， lower system losses and smaller size. The typical reference capacity SVG that RXPE has researched and developed is 160Mvar.

The SVG products of RXPE have been widely used in many indusiry fields such as metallurgy, electric power, coal mine,nonferrous metal,electrified railway,wind power generation, military project and vessel field.

RXPE provides the whole solution for improving power factor, optimizing the control and energy saving. RXPE's sales network not only has spread over china domestic but also extend to overseas countries such as German, Italy, India,Turkey,Vietnam,Thailand,Myanmar,Nigeria,Sudan and Brazil.

RXPE owns capaWe R&D and technical team and also the world leading power electronics test base wnich equipped with a 66kV/10000kva HV power station, the sole SVG HV full load test center and the unique load test center for special use of HV inverter, it can satisfy the needs of RTDS and the whole process of full load test.

RXPE is a high technology enterprise who passes ISO9001,ISO14001 and OHSAS18001 system certification, it possesses powerful origial independent innovation ability.

RXPE dedicates to the development of reactive power compensation technology and improving the power application in the world. Providing energy-saving, cost reducing and safety guaranteed products is the responsibility of RXPE. Our mission is to create a green, intelligent and efficient power world.

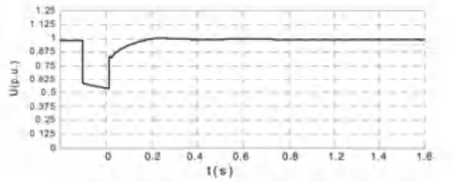
Current Severe Threatens to Grid

Grid voltage quality is evaluated by stability, symmetry and sinusoid performance usually. Because of wide application of modern electronic non-linear loads, the grid power quality is seriously affected, and the main interference sources are power electronic switching devices and frequently varied loads.

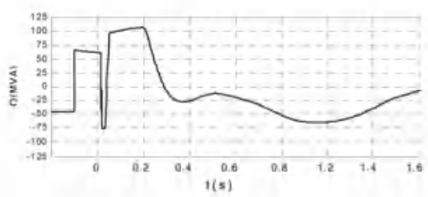
◆ The power transmission system lacks of timely var regulation .Thus surge are easily enlarged and the system stability is reduced
◆ The load center is lack of rapid var support,thus lower voltage even voltage crash easily caus
◆ The low power factor results in grid losses ,higher production cost and lower productivity
◆ Varied var causes grid voltage sag, voltage fluctuation and voltage flicker.In severe condition, it may cause transmission and protection failure, even production stop
◆ A great deal of harmonic current generates grid voltage distortion.It is even the recessive killer of grid:

- Protection and safe devices misact
- Enlarge harmonic current of capacitor banks,making capacitor over load or over voltage,even burn out
- Increase transformer losses,causing transformer over heat
- Induce electric equipment heat,motor torque unstable even damage
- Promote the aging of electric equipment,making it easily be broken
- Reduce arc frnace efficiency
- Interfere communication

◆ Different loads cause 3 phase unbalance,generating negative sequence current and causing motor rotor vibration.



Grid voltage recover process when SVG in service



Output reactive power of SVG

The Best Solution——SVG

Now the optimal solution is to use SVG,which increases stability and transmission capability of power Grid , and eliminates var impact,harmonic and unbalance.

SVG Operating principle

SVG is the representative of newest technology in var compensation area.SVG is connected in parallel to the grid, similar to a variable var current source .Its var current can change following the vary of load var current rapidly and automatically. Since the response speed of SVG is very fast, it is also called Static Synchronous Compensator.

SVG's fundamental configuration is 2-phase or 3-phase self commutated bridge circuits adopting full ontrolled power electronic semiconductor devices (like IGBT).Through reactors the SVG is connected in arallel to the grid.By adjusting the output voltage amplitude and phase angle or direct controlling AC side current, the SVG can absorb or generate var according to the load reactive power or the grid oltage level.

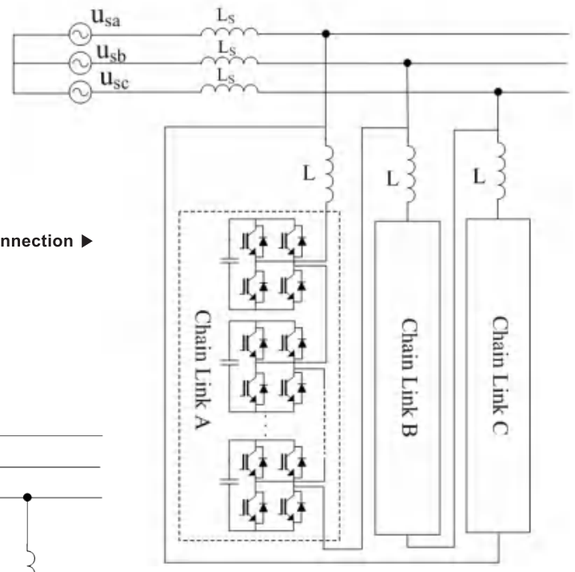
Work mode	Shape of wave	Description
No load	U_I U_S (a) $U_I = U_S$	If $U_I = U_S$, SVG has no compensation capability
Inductive operation	U_S U_I I_L (b) $U_I < U_S$	If $U_I < U_S$, SVG can output inductive current continuously
Capacitive operation	U_I U_S I_L (c) $U_I > U_S$	If $U_I > U_S$, SVG can output capacitive current continuously

RXPE Topology SVG Power Units With Series Connection

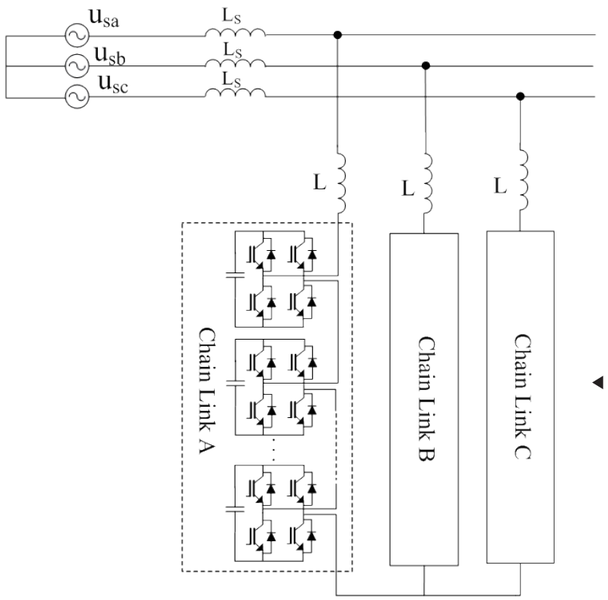
The dopted topology is:Transformer less cascaded H-Bridge Multilevel Converter. The terms of Cascaded H-bridge means that the VSI is composed of several H-bridge connected in series; the terms multilevel means that the output voltage of the VSI assumes several distinct values. This topology can be used in two connection schemes: Delta connection and Wye connection.

SVG Topology graph

Delta Connection ▶



Topological graph of power units with delta connection



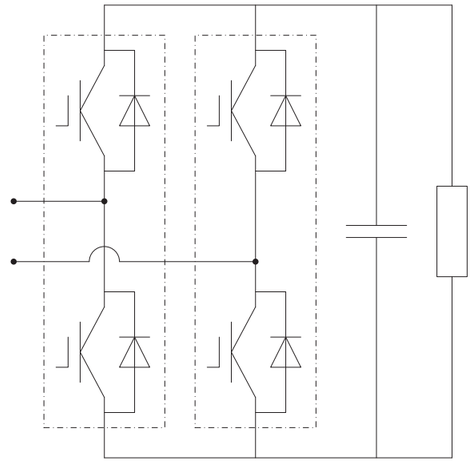
◀ Wye Connection

Topological graph of power units with Wye connection

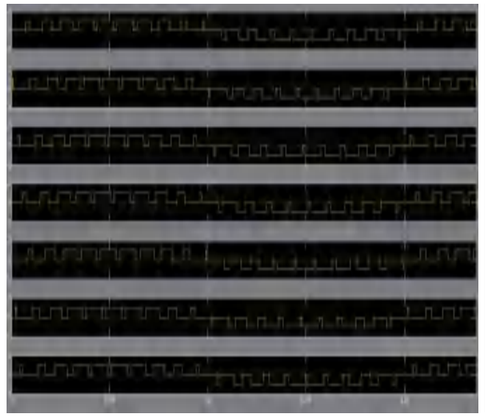
Power Unit

Features of power unit

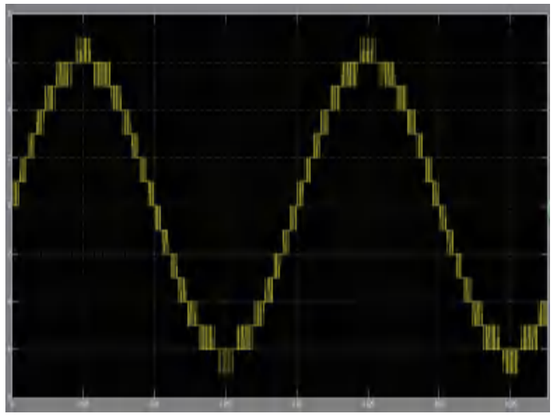
- IGBT parallel connection to realize high power
- Smaller reactor impedance and volume
- Higher power density



Structure of cascaded multilevel SVG



Modulation and output waveform of power unit



Output voltagewave form of cascaded multilevel SVG

SVG System Structure Component

Container wind cooling

Control system

Cooling system

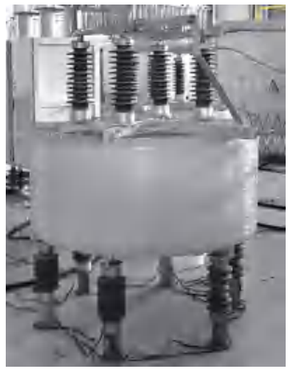
Power unit

Charge system

Container water cooling

Control system

Cooling system



Charge system

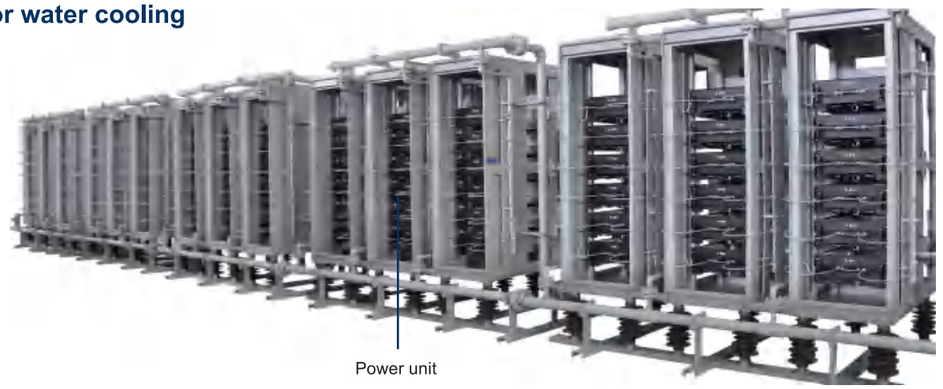
Indoor wind cooling

Control system

Power unit

Charge system

Indoor water cooling



Power unit

Application Fields of RXPE SVG

Long distance power transmission

At present,there is a worldwide trend to use big power Grid and long distance power transmission.This causes high Power losses,at the same time forces the power transmission and distribution system to increase its capacity. SVG can increase the performance of transmission&distribution of power system, which has been proven worldwide.Therefore, installing SVGs at one or several places of the grid can reach the following goals:

- stablize weak system voltage
- reduce the lose of power transmission
- increase transmission capability
- increase transient stabilization limit
- damp small interference
- boost up voltage control and stabilization capability
- attenuate power oscillation

SVG system becomes a strong technical support for grid interconnection operation.

City second level substation（66/110kV）

In regional grid,several capacitor banks are put into or out of service group by group to compensate system var and improve power factor.This way can only offer capacitor var and cannot follow the load variation. Sometimes power factor is ensured with overfed capacitive var,driving up the line voltage and harming the facilities and system stability.RXPE SVG can fastly and precisely compensate both capacitive and inductive var,stabilize line voltage, increase power factor,at the same time solve var overfed problem greatly.Installation of new SVG system can still use original fixed capacitor groups and thyristor controled reactors(TCRS), which is the most effective way to improve regional grid quality with minimum investment but best result.

Arc furnace

As a nonlinear and ruleless load,arc furnace will make a series of strong impact on the grid as follows:

- Negative sequence current causes serious 3-phase unbalance
- Many high order harmonics,including even-order and odd-order harmonics, Make the voltage distortion more complicated
- serious voltage flicker
- low power factor

The only way to solve this problem for clients is to install fase response Dynamic var compensator.RXPE SVG system responses less than 5 ms,which offers arc furnace with fast var support, and significantly reduces voltage flicker,stablilizes line voltage,increases metallurgy power output,as well as productivity.SVG has the function of phase compensation and can eliminate the 3-phase unbalance caused by arc furnace.The assistant filter is able to remove harmful high order harmonics and offer capacitive var to increase power factor.

Rolling mill

When rolling mill and other industrial unsymmetrical load are put into service,the varied var requirements will cause the following influences to the grid:

- Cause voltage drop and fluctuation,thus reduce efficiency.Electric facility even cannot work properly.
- Low power factor
- Harmful high order harmonics,mainly 5,7,11,13 order and interharmonics, causing serious voltage distortion

RXPE SVG can solve these problems perfectly,with keeping line Voltage stable,low harmonics and high power factor

Electric locomotive power supply

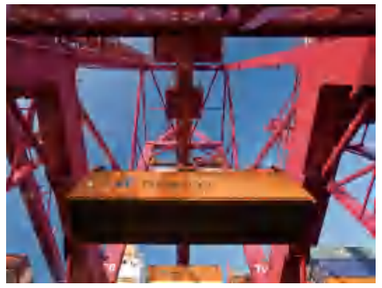
The mode of electric locomotive transportation protects the environment ,but seriously pollutes the grid at the same time.Since electric Locomotive uses single phase power supply, several power quality will Arise such as 3-phase unbalance,lower power factor,and negative sequence current . Now the only solution in the world is to install SVG system along the railway substation. Through the function of SVG, the 3-phase network is balanced and the power factor is improved.RXPE SVG has remarkably high ratio of performance to price, with solving the problem economically.

Hoister and other heavy industry loads

When hoister and other heavy industrial load operate,the Power grid will be influenced as follows:

- Cause voltage dip and fluctuation
- lower power factor
- Transmission equipment will generate harmful high Order harmonics

RXPE SVG can solve above problems perfectly.



Main Functions of SVG

• Improve the stability of power transmission

In long distance transmission system, SVG can not only compensate the power line losses caused by reactive power, increase line voltage and improve effective transmission capacity under normal operation, but also offer reactive power adjustment in time, damp system oscillation and improve system stability in case of fault.

• Maintain the receiving-end voltage level

Since high capacity load centers lack reavtive power support,it is easy to cause grid voltage dip, even cause voltage collapse. However, SVG is capable of fast var adjustment. Therefore ,the receiving-end voltage level is greatly stabilized.

• Reactive power compensation leading to high power factor and low line losses

Many types of loads need a mass of reactive when operation, such as asynchronous motors,arc furnaces, rolling mills and high rating rectifiers. At the same time, the upstream transformer and line impedance also generate reactive power,which still leading to low power factor.

For the power system,loads with lower power factor will increase the line losses,voltage drop and deteriorate voltage quality.Additionally, reactive power will reduce efficiency of power generation, transmission and distribution. For clients, low power factor will increase production costs.

• Restrain voltage fluctuation and flicker

Voltage fluctuation and flicker are mainly caused by rapid loads variation.This fast variation also causes the load current fluctuation dramatically.The current variation leads to system voltage losses changing very fast, which brings the receiving-end grid voltage flicker.The typical loads that cause voltage flicker are arc furnaces,rolling mills,electric locomotives,etc.

SVG can offer fast reactive power regulation, which mitigate voltage fluctuation and flicker easily caused by loads variation.

Now, SVG is the best solution to restrain voltage fluctuation and flicker.

• Mitigate 3-phase unbalance

In distribution network, there are a lot of 3-phase unbalance loads,typically like electric locomotives and arc furnaces. At the same time, line and transformer impedance unbalances can also cause voltage unbalance problem.

SVG can fast compensate negative sequence current caused by unbalance loads, which ensure balanced 3-phase grid current. Thus,it improves the power supply quality greatly.

Technical Advantages of SVG

SVG is the most advanced var compensator technology, which realizes an evolution of reactive power compensation mode based on voltage source converter. Big volume capacitors and reactors are no longer needed.

SVG uses HV IGBT with high switching frequency to realize reactive power regulation. Therefore, SVG has the following advantages compared with traditional compensation methods:

• Faster response speed

SVG response time：≤2ms.

Traditional static compensator response time： ≥10ms.

SVG can finish the transition from rated capacitive var to rated inductive var in a very short time.

This unexampled response speed makes SVG very suitable for impact load compensation.

• Stronger voltage flicker restrain capability

SVC can restrain voltage flicker to 2:1 in maximum,but SVG can achieve 5:1,or even higher.SVC cannot improve its capability for voltage flicker mitigation even with high capacity because of low response speed. But SVG can respond fast. So when its capacity is increased, the capability of voltage flicker mitigation can be further improved.

• Wide operation range

SVG can work from rated inductive power to rated capacitive power. So compared with SVC, the operation range of SVG is much wider.Furthermore,SVG can output rated reactive current even under low system voltage.

• Multiple compensation function

RXPE SVG is not only functioned as fast reactive power compensator,but also harmonics and unbalance compensator according to different demands of different clients.

• Low harmonic content

RXPE SVG utilizes SPWM technology. Therefore, it generates very low harmonics with compensating load harmonics at the same time.Thus, SVG becomes a true multifunctional compensator.

• Smaller floor space

HV big capacitors and reactors are not necessary anymore. SVG installation area is greatly smaller than that of the same capacity SVC, only 50% or even lower.

The Main Parts of The Wind Cooling SVG

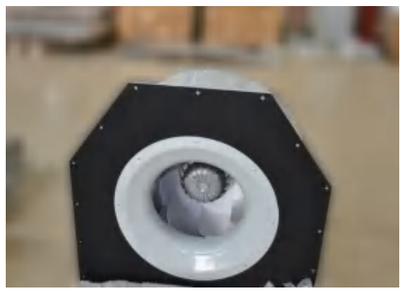
Exterior of Power cabinet of wind cooling SVG

The structure of power part consists of power units and cooling device. The device in the picture is wind cooling power cabinet.

Interior of power cabinet of wind cooling SVG

It consists of multiple power units which are self-developed by RXPE.

Wind cooling fan



The fan is made up with highly reliable metal material.

The Main Parts of The Water Cooling SVG

The interior of water cooling SVG power cabinet

RXPE's water cooling system has the advantage as below:

1. Higher cooling efficiency
2. Air-tight design provide higher protection level
3. The power units in the water cooling power cabinet adopt the design with most optimize intensive drawer type which is tight enough and easy to install

The exterior of water cooling SVG power cabinet

The exterior of water cooling SVG power cabinet

water cooling unit

Water cooling unit consists of stable parts such as ion exchange tank, water tank, stand-by pump and main pump

Core Electric Electronics Control Components of SVG

Control cabinet

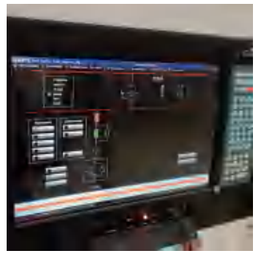
Power cabinet

IGBT module (international first class)

CPU board

PWM panel (pulse-width modulation)

Drive board



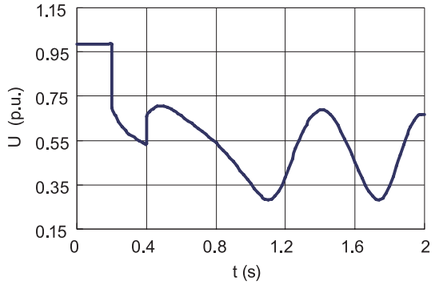
HMI integrative work station
(windows system with PLC)

Intensive drawer type power unit

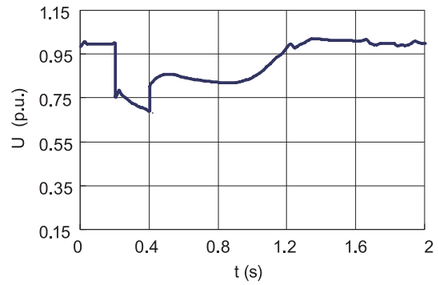
System Compensation Application

Restrain the system oscillation,improve the grid stability and guarantee the safe operation for the grid.

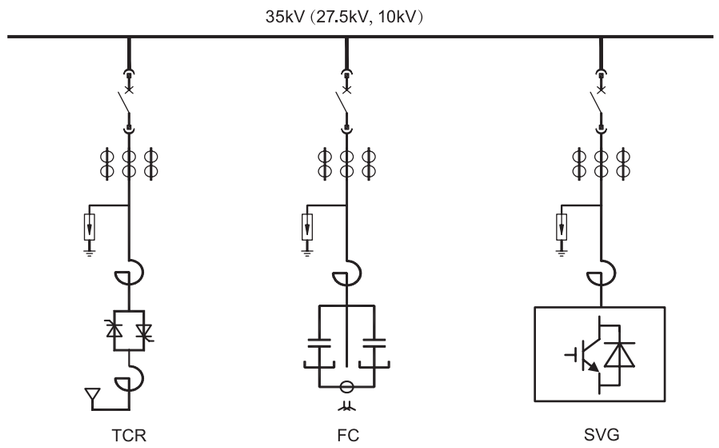
Voltage curve without SVG when failure



Voltage curve with SVG when failure



Because of larger and larger regional power grid,the capacity of the compensation needs to be larger accordingly. In the reactive power compensation system with several hundreds of MVA,the popular solution is to combine SVG with SVC in order to make full use of the faster response performance of SVG and the steady state performance of SVC, which optimizes the system in compensation performance,cost and reliability.



Load Compensation Application With Multifunctions

• Compensate the load reactive power

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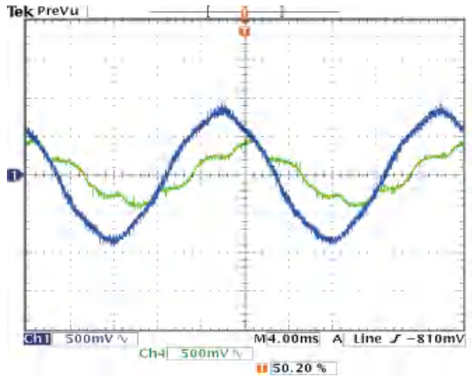
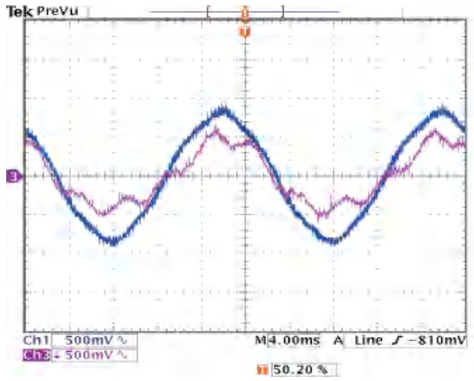


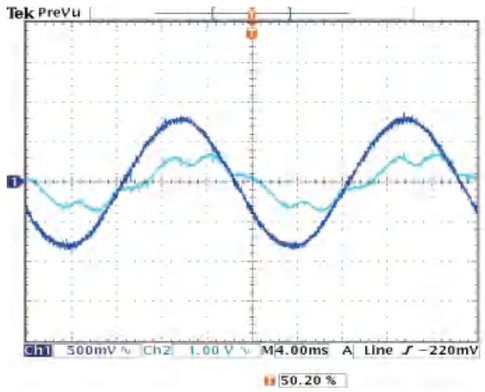
Voltage and current waveforms of grid without SVG



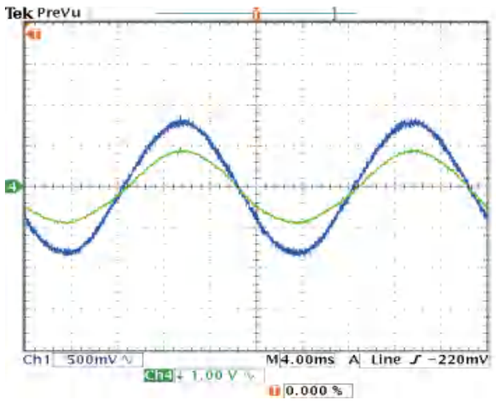
Voltage and current waveforms of grid with SVG

• Compensate the load reactive power and harmonics

SVG can compensate both the reactive power and harmonics



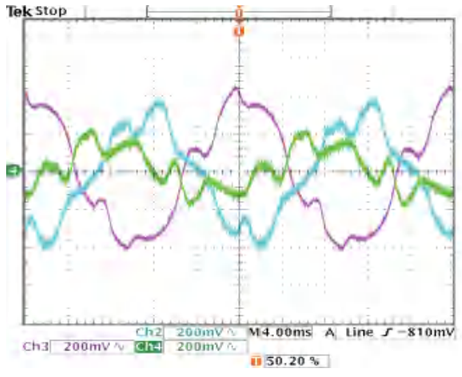
Voltage and current waveforms of grid without SVG



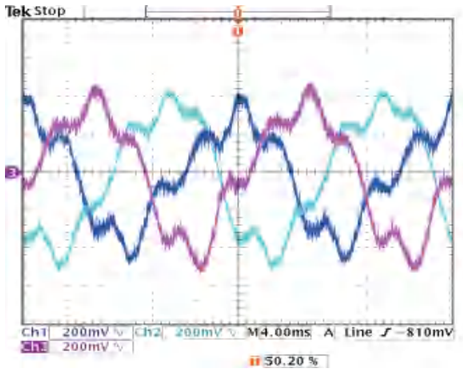
Voltage and current waveforms of grid with SVG

• Compensate the three phase load unbalance

The most effective negative current restraining equipment



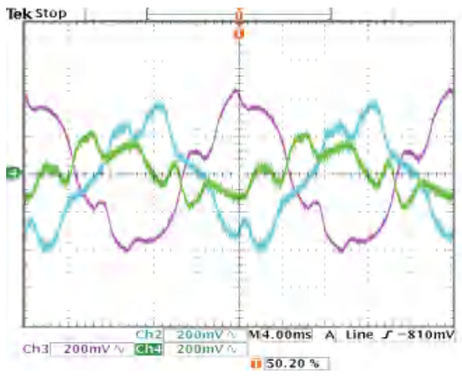
Voltage and current waveforms of grid without SVG



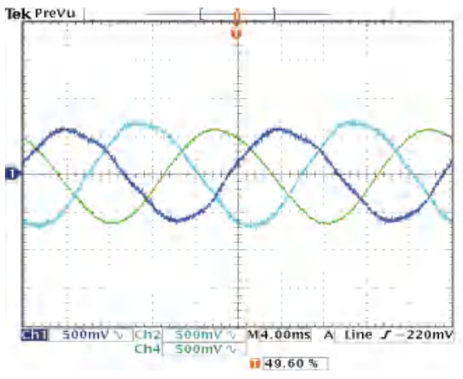
Voltage and current waveforms of grid with SVG

• Compensate the load reactive,harmonics and three phase unbalance

SVG can compensate the reactive power,harmonics and three phase unbalance.It is a perfect solution to greatly improve load electric power quality.



Voltage and current waveforms of grid without SVG



Voltage and current waveforms of grid with SVG

R&D and Manufacturing Platform

Intelligent high temperature aging room

Full load and multifunctional test platformfor power modules (1.1 times overload)

SVG electromagnetic compatibility test

Power units assembling line

Lightning strike test platform

PCB high and low temperature aging test box

RTDS laboratory

PCB board aging test instrument

The Supply Performance of RXPE SVG in The Worldwide

Supplied 100Mvar/31.5kV SVG to Poland ELMA company CMC steel mill electric arc furnace(with FC)

Supplied 14Mvar/33kV SVG to South Korea ASO TAKAMORI Photovoltaic

Supplied 40Mvar/34.5kV SVG to Mexico Diram-deacero electric arc furnace (with 40 Mvar FC 2sets)

Supplied 8Mvar/10kV SVG to Beinneun wind farm reactive power compensation project

Supplied 10Mvar/10kV SVG to Papua New Guinea national grid

Supplied 20Mvar/33kV SVG to Malaysia 50MW photovoltaic plant

Supplied 45Mvar/35kV SVG with active power filter to Russia Tominsky GOK

Supplied 10Mvar/27.5kV SVG to Russian electrified railway (-30℃ working temperature)

Respresentative Cases of RXPE SVG Solution

Flicker Suppression Of Electric Arc Furnace Load In Steel Plant

Customer Needs

Electric arc furnace(EAF), a kind of electric furnace which make use of heat from electric arc to smelting metal. The character of electric arc furnaces operating load are no-linear and strong time-varying, which will cause many system power quality problems such as grid voltage flicker and fluctuation, large negative sequence component, more harmonic, low power factor of power grid.

Poland Elma Company CMC Steel Plant uses 31.5kV/105MVA EAF with top charging structure.In the past, fixed capacitor was used for reactive power compensation on site, and there were power quality problems such as low power factor and excessive flicker.

RXPE Solution

According to data analysis and confirmation of technical indicators, the 31.5kV/100MVar delta-connected SVG device combined with FC fixed compensation equipment is used to compensate reactive power, harmonics, voltage imbalance and grid voltage fluctuations in the on-site electric arc furnace smelting process comprehensive treatment of power quality issues such as flicker.

The 31.5kV/100Mvar delta-connection SVG device of the project is an outdoor container structure, including 6 power containers and I control and water cooling system container. The power valve bank adopts a water-water cooling system, which can provide good heat dissipation conditions for the power valve bank and ensure safer and more stable operation of the equipment.

Technical Features

Direct connection to EAF bus without transformer

RXPE SVG is directly connected to the EAF bus, avoiding all converter transformer drawbacks .This is important for achieving the best possible flicker reduction by compensating the furnace current including DC components. DC components in the EAF current are common during EAF energizing and bore down period of the melt. With a converter transformer saturation can happen due to DC components in the current, and flicker reduction will suffer as a saturated transformer does not allow for fast and accurate reactive compensation. Similarly, the harmonic compensation performance is also a 忏 ected by the magnetic saturation performance of the transformer.

Redundancy design of power unit

The RXPE SVG has power unit bypass function, with 4 units per phase that can be automatically bypassed in the event of failure without affecting the normal operation of the device.

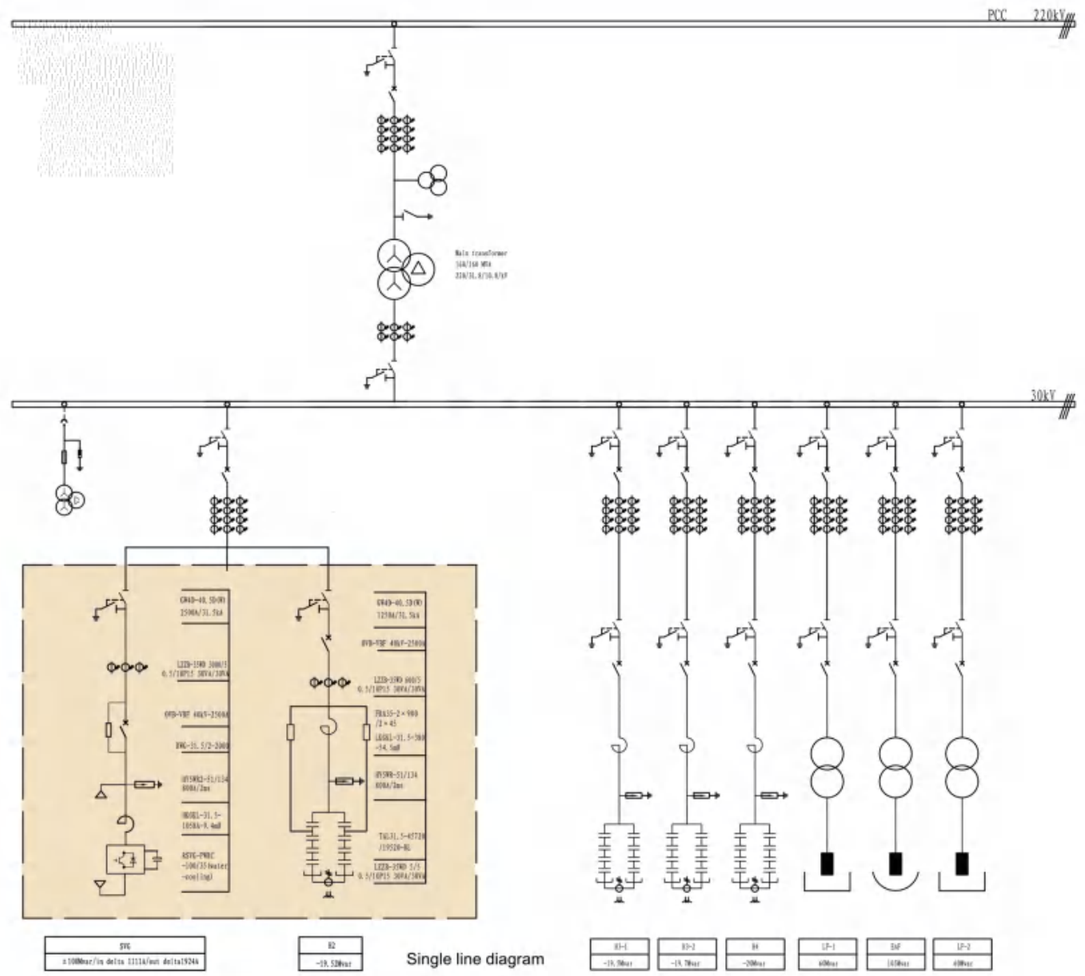
Hall current sensor for EAF current measurement

It is mainly the EAF that generates flicker, requiring accurate measurements of the individual phase currents. Due to the DC component of EAF current, the output distortion of conventional current transformers will be caused by magnetic saturation.

Hall current sensor is installed in the EAF branch, and its bandwidth is DC~100kHz.

Power container

Control container



Single line diagram

Photo of project on site

The performance of flicker suppression

The SVG on this site is mainly for suppressing the grid voltage fluctuation and flicker during the EAF is in production period. Before the SVG put into operation, the 31.5kV busline voltage flicker measurement data shown as figure 1, the maximum value of Pst can be reach at 19.0 and Plt value also maximumly reach at 10.9. According to the measurement of flicker tester, the Plt value on 220kV bus line(95% probability value) reached at 2.064.

After SVG put into operation, it effectively compensate the reactive power impact during EAF in production. The power grid voltage and flicker condition has been significantly improved. After the SVG put into operation, The Pst and Plt value on 31.5kV busline are shown as figure 2.

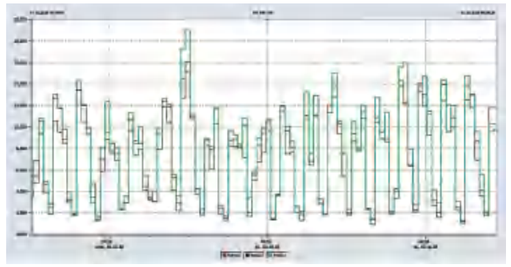


Figure 1 Pst for 31.5kV,without SVG

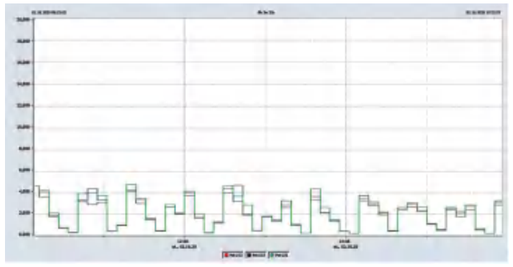


Figure 2 Pst for 31.5kV, SVG is running

The maximum value of power grid voltage Pst has been decreased to around 5.0 and Plt is around 3.12. The Plt value of 220kV busline(95% probability value) decrease to around 0.649.

Performance criteria	Before SVG put into operation	After SVG put into operation	Suppression ratio
31.5kV Pst (maximum value)	19.0	5.0	3.8
31.5kV Plt (maximum value)	10.9	3.12	3.49
220kV Plt (95% probability value)	2.064	0.649	3.18

Power factor correction performance

The active power, reactive power and average power factor curve is shown as figure 3, the reactive power impact is very obvious and the average power factor is only around 0.83. Low power factor will cause the industry user to be fined by local power grid company, so installing reactive power compensation is very necessary.

After SVG put into operation, the active power, reactive power and average power factor curve is shown as figure 4. SVG is capable to compensate the reactive power during grid operating and the over compensate&under compensate condition doesnt exist. After compensated by SVG, the average power factor on 31.5kV busline is greater than 0.99 and the power factor on 220kV PCC point is also greater than 0.95(tanφ<0.3) Generally, the overall performance of SVG is higher than the expectation on technical agreement.

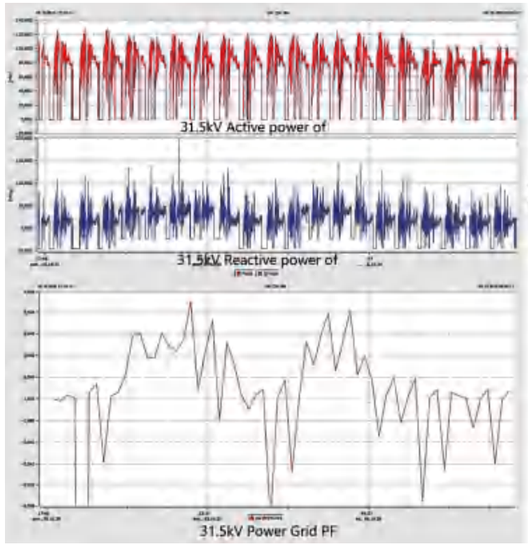


Figure 3 Active power、reactive power and PF
SVG is not operating

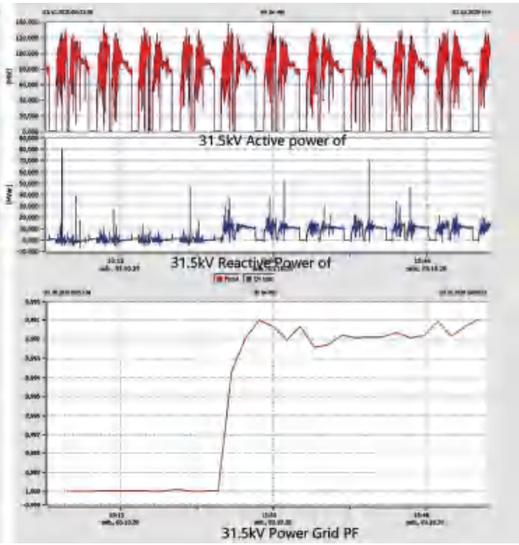


Figure 4 Active power、reactive power and PF
SVG is operating

Customer Benefits

The 31.5kV/100Mvar containerized water cooling SVG supplied by RXPE effectively mitigated the multiple power quality issues during EAF production in CMC Zawiercie, steel plant in Poland.

1）The Plt value decrease from 2.064 to 0.649 on 220kV PCC point during grid in production, it fully comply with the technical requirement which stated on the technical agreement that the PLT value(95% probability value) not exceeding 0.8. The flicker suppression ratio can be reach at 3.18 excluding the power grid background flicker condition.

2）The power factor on 220kV PCC point is greater than 0.95(tanφ<0.3), it fully comply with the requirement stated on the technical agreement which is tanφ<0.4

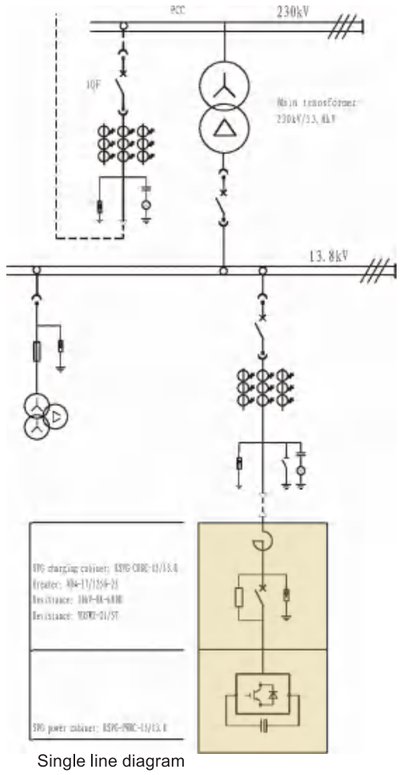
3）After the SVG put into operation, the harmonics and voltage unbalance on 220kV PCC point fully comply with the requirement of technical agreement.

Power Factor Compensation In Steel Plants

Customer Needs

Mexico Deacero Saltillo steel plant 15Mvar 13.8kV SVG project which is located in the city of Saltillo, north of Mexico. The Statcom equipment is installed in the Deacero Steel Plant's substation and officially put into operation on December 8, 2020.The project uses containerized Statcom equipment, model RSVG-15-13.8-TWOY.

Control objectives: power factor ≥ 0.97 (partial inductance), harmonic requirements meet Mexico national standards(IEEE 519-2014).



Single line diagram

Photos of project on site 1

Photos of project on site 2

RXPE Solution

1. Load condition

The main load of Deacero steel plant in Mexico is the wire rolling mill. Its maximum reactive load is about 11Mvar, its main harmonic is 5th, and its maximum harmonic current is about 100A.

On-site PCC checkpoint is on 220kV side, supplying power to the factory through 220kV/13.8kV main transformer.

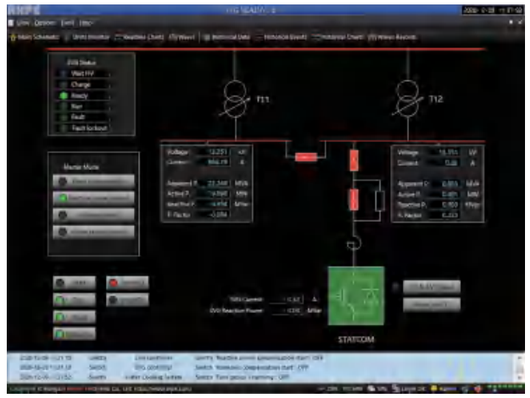
2. Compensation scheme

STATCOM equipment is a cascade structure directly connected to the 13.8kV busbar, and the control targets are power factor and harmonics.

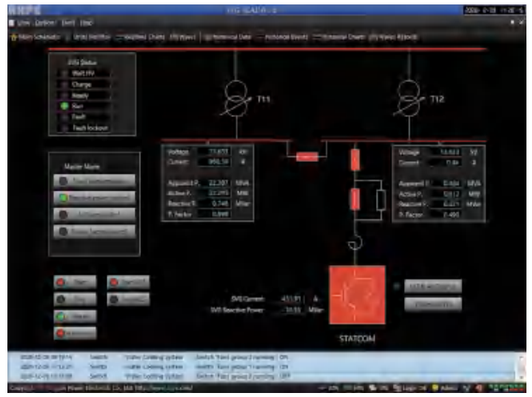
The on-site assessment measurement point is at the remote end, and the remote voltage and current signals cannot be collected. Therefore, the reactive power is compensated by setting the gain coefficient and the offset coefficient, and the harmonics are dynamically compensated on-site.

Customer Benefits

1.On-site power situation and compensated power factor

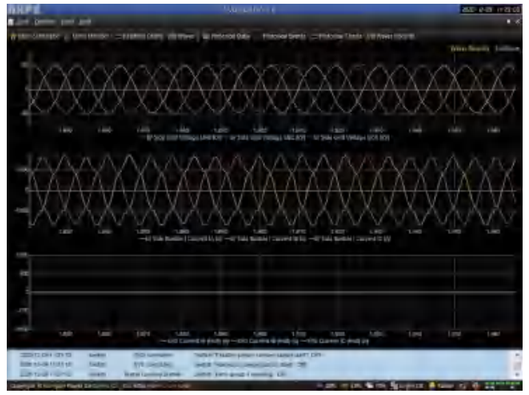


Main interface of equipment operation (before compensation)

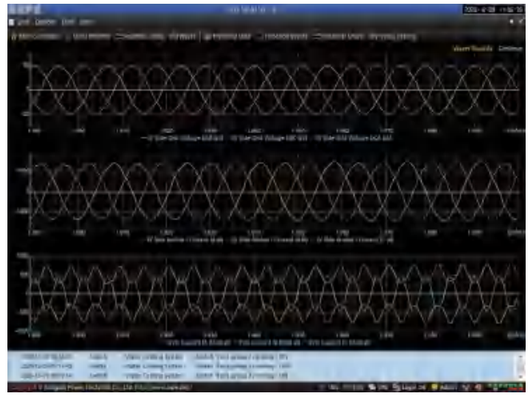


Main interface of equipment operation (after compensation)

2. Comparison of grid-side voltage and current waveforms before and after compensation



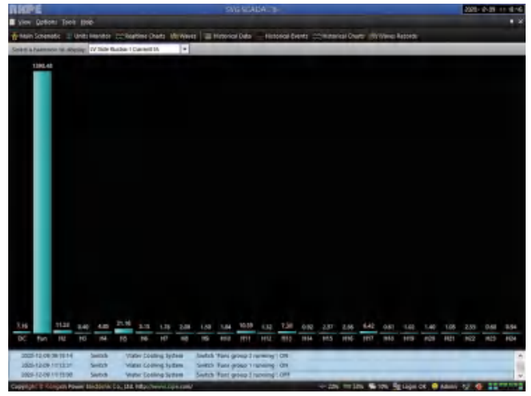
Grid voltage and current waveform before compensation



Grid voltage and current waveform after compensation

3. Grid side current spectrum before and after compensation

Grid-side current spectrum before compensation



Grid-side current spectrum after compensation

Tenaris Tamsa 34.5kV/150Mvar STATCOM

Customer Needs

RXPE provided a set of 34.5kV/150MVar delta connection STATCOM based on Press Pack IGBT(PP-IGBT) to Mexico Tenaris Tamsa steel plant in early 2024 to replace the SVC device used for electrical arc furnace power quality control. The STATCOM worked together with a group of filtering capacitor banks (H2+H3+H4) with 110MVar fundamental compensation capacity to control all power quality issues such as voltage fluctuations and flicker, harmonics, unbalance and system input power factor during the operation of one 135MVA top feeding arc furnace and two refining furnaces (with capacities of 24MVA and 30MVA respectively) in Tenaris TAMSA steel plant in Mexico.

RXPE Solution

The 34.5kV/150MVar STATCOM is indoor type with water-air cooling mode, the power valve part used delta connection topology with 30 power modules (include 3 redandant power modules with online bypass function) each phase, the power module used 4500V/2000A PP-IGBT and 2800V/9000uF film DC capacitor. The control system also used redandant design, if the activated controller failed the hot standby controller will auto-switch into operation to keep STATCOM continuous running.




Photos of peoject on site after installation

Customer Benefits

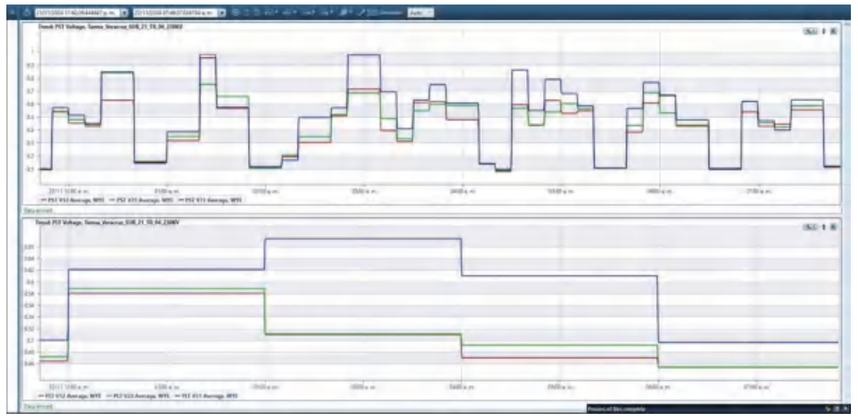
The 34.5kV/150MVar STATCOM device was put into operation in November 2024, and after operation, the power quality technical indicators such as grid voltage fluctuations and flicker in the on-site electric arc furnace production process were significantly improved, and the production efficiency of the electric arc furnace was also significantly improved.

Compared with SVC device compensation, the 34.5kV/150MVar STATCOM compensation improved the short time flicker (PST) supress ratio from 1.72:1 to 4.4:1 and long time flicker ratio from 1.67:1 to 4.2:1 as shown in below table1. The harmonics, unbalance and power factor technical indicators also significantly improved and comply with related IEEE and IEC standards.

Table1: Compensation of flicker compensation result for STATCOM and SVC

Condition	PST value	PST supress ratio	PLT value	PLT supress ratio
Without compensation	3.80	-	2.82	-
SVC compensation	2.20	1.72 : 1	1.69	1.67 : 1
STATCOM compensation	0.86	4.4 : 1	0.67	4.2 : 1

PST and PLT value curve with SVC compensation during EAF production



PST and PLT value curve with STATCOM compensation during EAF production

Improve Power Quality Of Photovoltaic Power Station

Customer Needs

In March 2016, it was discovered through the power quality monitoring system that the harmonics of the 35kV busbar of Huancui mountain Photovoltaic Power Station exceeded the standard. The Electric Power Research Institute organized several special tests and analyses. In the power quality test link, the measurement points were selected from the opposite side Wayao port station (35kV access point), the high and low voltage side of the main transformer, and the collector line side. , Found that the 5th and 7th harmonic current exceeding the standard is caused by the photovoltaic power station. The specific harmonic content is shown in Table 1. Affecting the safe and economic operation of the power station, the photovoltaic power station actively started the treatment project.

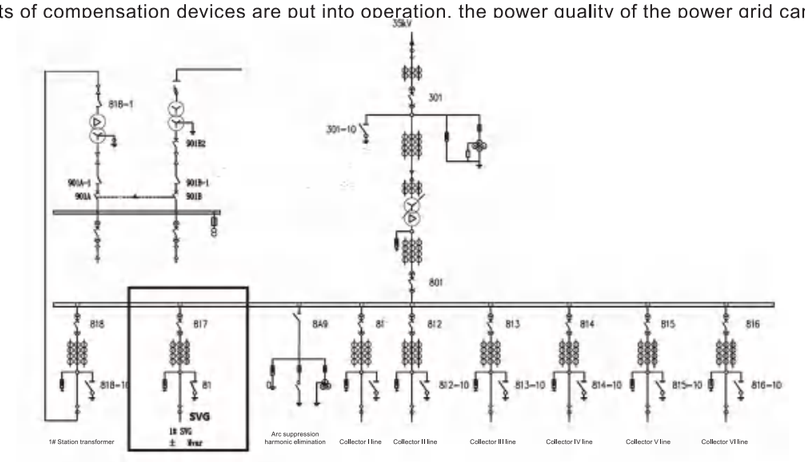
Table1 Harmonic current test results of photovoltaic power station

Harmonic current (A)	35kV test condition			10kV test condition		315V test condition	
		Operation test of high voltage side of main transformer	National standard limits	Operation test of low voltage side of main transformer	National standard limits	Inverter test	National standard limits
	3 rd	2.61	4.5	9.45	27.38	5.42	69.18
	5 th	15.36	4.68	54.05	27.38	25.86	72.91
	7 th	6.03	3.64	22.46	20.53	13.48	56.19

RXPE Solution

Considering the harmonic characteristics, engineering cost, construction difficulty, and technological advancement of photovoltaic power stations, it is recommended to adopt a centralized harmonic control method. 10kV dynamic reactive power compensation device (SVG) (with source filtering function) is installed to automatically detect and control the 2~13th harmonics.

The overall system composition of Huancui mountain photovoltaic power station is shown as below. Install SVG equipment in 10kV bus section. SVG can compensate for the reactive current on the load side to improve the power factor of the power grid; SVG and centrally control the harmonics and has the ability to comprehensively compensate for the 2 to 13th harmonics. After the two sets of compensation devices are put into operation, the power quality of the power grid can be effectively improved.



Huancui mountain photovoltaic power station system

The SVG controller samples the grid voltage and current in real time, and realizes the detection function of load current harmonic component through the command current detection module. After the reverse polarity of load current harmonic component is used as SVG command current, through current closed-loop control and PWM modulation, SVG outputs the expected compensation current with reverse polarity of load harmonic current, so as to offset the harmonics in the grid.

In view of the harmonic characteristics and design defects of huancui mountain photovoltaic power station, install SVG equipment in 10kV bus section to centralized harmonic control. The project was put into operation in May 2018.

The actual device of SVG on site is shown in figure as bellow, and the parameters of SVG device are shown in Table 2.

Field application of SVG device

Rated voltage	10kV
Rated capacity	Rated capacity 4Mvar
Overvoltage multiple	1.2 p.u
Operating frequency range	45-55 Hz
Harmonic compensation capability	2-13 harmonics
Connection method	Y
Responding speed	<5ms

Table 2 SVG parameters

Customer Benefits

In order to verify the actual application effect of the system, continuous tests were carried out on the power quality management effect before and after the SVG was put into use, as follows:

Figure 1 (a) and (b) respectively show the 35kV side harmonic voltage spectrum diagram when SVG is not put into operation at Wayao port of the photovoltaic power station and the opposite station. Figure 2 (a) and (b) respectively The harmonic voltage spectrum diagram of the SVG 35kV side put into operation at Wayao port of the photovoltaic power station and the opposite station is given. Through comparison, it can be concluded that when the active filter device is used, the 35kV harmonic voltage is greatly reduced and the filtering effect is significant.

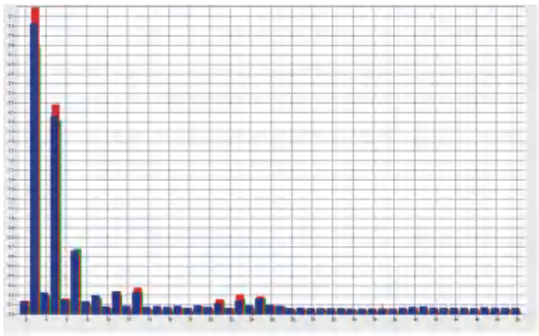


Figure 1 Harmonic voltage spectrogram of not used SVG photovoltaic power station side

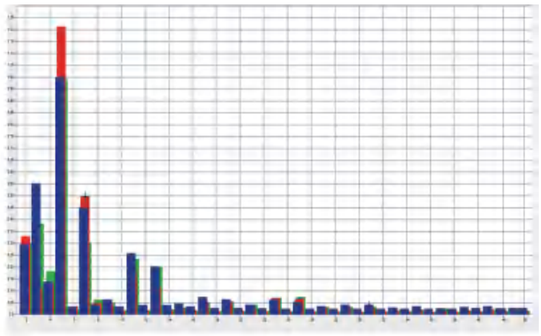


Figure 2 Harmonic voltage spectrum at the wayao side of the SVG not put into use

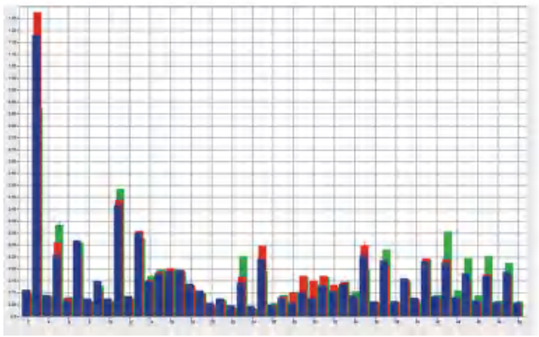


Figure 3 Harmonic voltage spectrum of the SVG photovoltaic station side

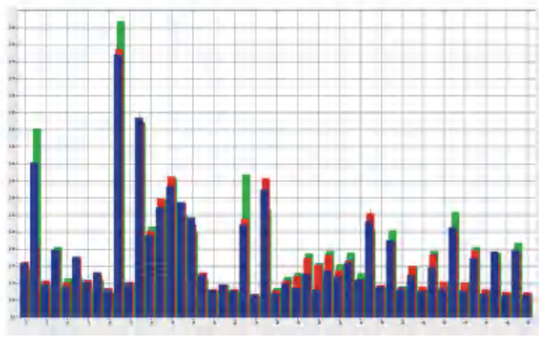


Figure 4 Harmonic voltage spectrum at the wayao side of the SVG put into use

Table 3 and 4 respectively show the comparison of the 35kV harmonic voltage and harmonic current data of the photovoltaic power station; when the SVG is not put into use, the total harmonic distortion rate of the three-phase voltage on the 35kV side and the 3rd and 5th harmonic voltage The content rate exceeded the standard, and the voltage total harmonic distortion rate reached 6.27%, far exceeding the national standard limit of 3.0%. After the SVG is put into use, the voltage content rate of each sub-harmonic and the total harmonic distortion rate of the voltage all meet the requirements of the national standard.

Harmonic order	A phase		B phase		C phase		National standard limits
	√	×	√	×	√	×	
3	1.24	3.88	1.32	4.08	0.97	4.01	2.4
5	0.54	4.19	0.58	4.60	0.72	4.07	2.4
7	0.49	2.26	0.42	2.29	0.49	2.38	2.4
THD	1.78	6.06	1.93	6.27	1.73	6.00	3.00

Table 3 Comparative analysis of 35kV side harmonic voltage（unit：%）

Before the SVG was put into use, the 5th and 7th harmonic currents of the three-phase 35kV side exceeded the standard. After being put into use, the harmonic currents of each order have not exceeded the standard, and SVG has achieved a good harmonic control effect.

Harmonic order	A phase		B phase		C phase		National standard limits
	√	×	√	×	√	×	
3	0.74	2.09	0.59	1.88	0.66	2.61	4.50
5	1.15	13.46	0.97	15.36	1.01	13.45	4.68
7	1.24	5.28	0.91	5.58	1.26	6.03	3.64

Table 4 Comparative analysis of harmonic currents on the 35kV side（unit：A）

Technology promotion prospects

This case uses a high-voltage active filter device, which is suitable for new energy power stations with harmonics exceeding the standard.

Mengdong Xilingol League Aqi 500kV Substation SVG

Project Background

As of March 2021, the Ximeng UHV AC/DC transmission project has 5 thermal power plants and 34 wind farms connected to the grid, with a thermal power installed capacity of 5980MW and a total wind power connected capacity of 6773MW. The Ximeng wind fire bundling and sending system is sent out through ultra-high voltage DC and ultra-high voltage AC with series compensation. In order to improve the stability of new energy grid connection, RXPE increased two sets of 35kV/60Mvar SVGs for Mengdong Power Grid Company in July 2020, which were installed at the Berigutai 500kV gathering station of Mengdong Power Grid Company.

RXPE Solution

RXPE provides two sets of 35kV/60MVAR SVGs for Mengdong Power Grid Company. The SVGs are wye connection topology, high-voltage suspension scheme, indoor installation, and water air cooling method.

The on-site SVG equipment layout plan is shown in Figure 1. The entire device consists of a control system, water cooling system, external cooling fan, power cabinet, reactor, charging resistor, bypass circuit breaker, etc.

The physical photos of the on-site SVG primary equipment, power cabinet, and control cabinet are shown in Figures 2-4.

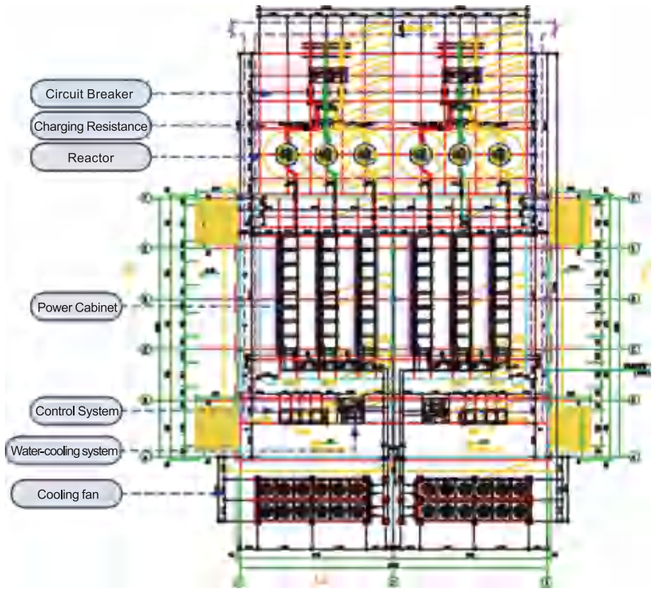


Fig. 1 SVG Layout Plan

Fig. 2 SVG on-site photos (outdoor primary equipment)

Fig. 3 SVG on-site photos（Indoor power cabinet）

Fig. 4 SVG on-site photos（control cabinet）

Technical characteristics

• Control system redundancy

The SVG control system has redundancy function and is implemented by two sets of controllers, one working and one standby. In case of abnormal operation of the working controller, it is possible to smoothly switch to the standby controller to continue operation. Ensure the reliability of SVG continuous operation.

Both controllers collect the same analog and switching signals. The difference is that the analog signal comes from different windings of PT and CT in the station, and the switch signal also comes from different relay contacts in the station. Maximizing the reliability of the collected signal. Redundant function monitoring through high-speed fiber optic communication can quickly and stably complete controller redundancy switching.

• Power unit redundancy

The SVG power unit has N+2 redundancy function, and is equipped with a permanent magnet mechanical bypass switch inside. In case of power unit failure, it can automatically bypass without affecting the normal operation of the equipment.

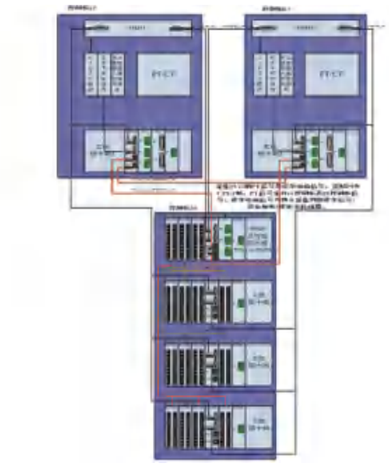


Fig. 5 SVG controller redundancy scheme

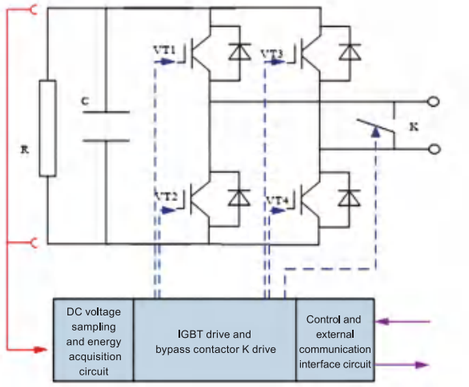


Fig. 6 SVG Power Unit Scheme

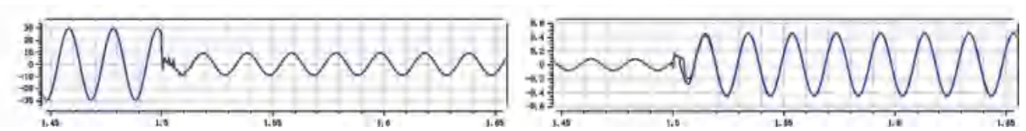


Fig. 7 SVG Low Voltage Ridethrough Response Waveform

Operation effect

The two sets of equipment were connected to the grid for operation in December 2020. On March 28, 2021, they passed the on-site system test of the Static Var Generator (SVG) organized by the North China Electric Power Research Institute, and all performance met the test requirements. At present, the two sets of equipment have been operating stably and the compensation effect is normal.

SVG has control system redundancy function and also has power unit chain module bypass function. The above two functions greatly increase the long-term stability of the equipment and can meet the high and stable operation requirements of unmanned substations for reactive power compensation equipment.

SVG Used For Voltage Imbalance Control In Power Grids

Project Background

With the rapid development of electrified railways, their impact on the power supply and consumption system has become increasingly prominent. Because the railway is a single-phase load of 27.5kV, if balanced compensation is not carried out, it will cause serious voltage imbalance at the public grid connection point, which will have a serious impact on other loads at the grid connection point.In recent years, the Alashankou crude oil station has been affected by the surrounding electrified railways, resulting in an unbalanced 110kV power supply voltage and frequent tripping of the 6kV motor load current protection action, seriously affecting the stability of energy transmission.

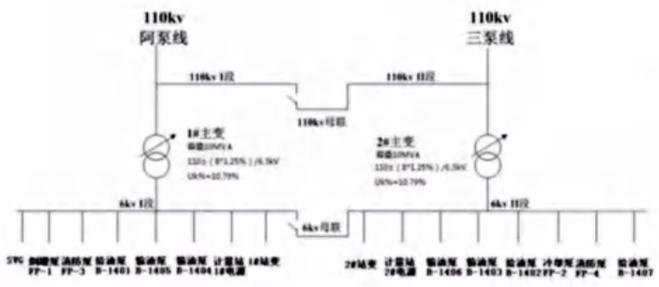


Fig. 1 Field Main Wiring

The on-site 6kV voltage imbalance test data is shown in Figure 2. According to the analysis of test data, the highest value of voltage imbalance in the power grid is 3.5%, with a 95% probability of a high value of 0.96%. According to the requirements of the national standard "GBT 15543-2008 Electric Energy Quality - Three Phase Voltage Imbalance", the negative sequence voltage imbalance generally does not exceed 1.3% and short-term does not exceed 2.6%.

The existence of negative sequence voltage will lead to a large negative sequence component in the pump current, and the presence of negative sequence current will cause the device to act as an unbalanced protection.

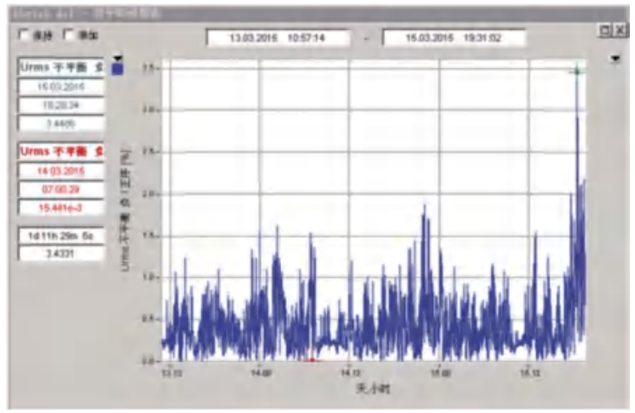


Fig. 2 6kV voltage imbalance (SVG not in operation)

To solve the problem of pump shutdown on site, Rongxin Company provided a set of 6kV/3.6Mvar SVG to the site to address the voltage imbalance in the 6kV system side power grid. The equipment adopts a corner joint topology structure and is installed in an air-cooled indoor cabinet style. The on-site photos are shown in Figure 3.

Fig. 3 Photos of SVG equipment

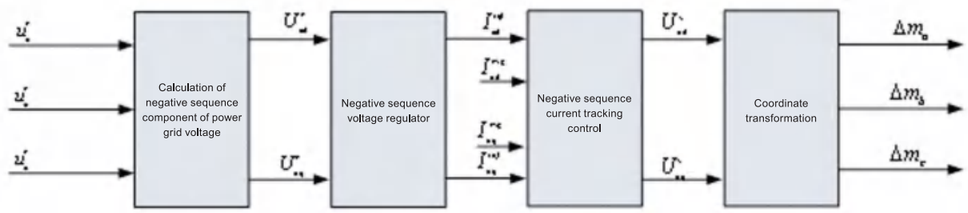


Fig. 4 Negative sequence voltage suppression control block diagram

The voltage imbalance data after SVG operation is shown in Figure 5.

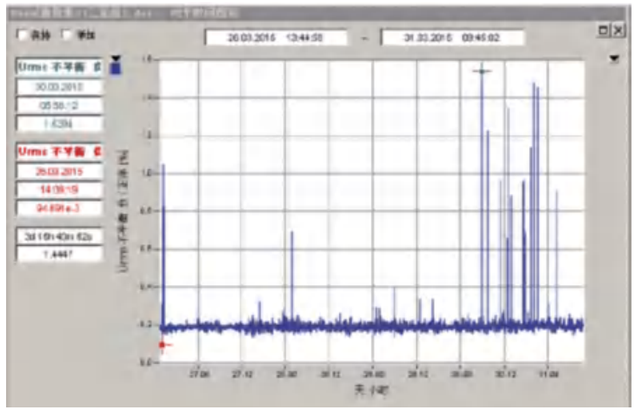


Fig. 5 6kV voltage imbalance (SVG operation)

According to the analysis of test data, the highest value of voltage imbalance in the power grid is 1.54%, with a 95% probability of 0.21%. The voltage imbalance has been significantly improved. Meet the requirements of the national standard "GBT 15543-2008 Electric Energy Quality Three Phase Voltage Imbalance". After the SVG was put into operation, the sudden shutdown of the on-site pump did not occur again.

Unbalance compensation of railway traction power supply system

Customer Needs

With the rapid development of electrified railways, its influence on the power supply and consumption system is also increasingly prominent. Because the railway traction system is a 27.5kV single-phase load, if the balance compensation is not carried out, it will cause a serious imbalance in the voltage of the public grid connection point, especially in the weak area of the power grid with small short-circuit capacity, which will cause a serious damage to other loads connected to the public grid. For example, the negative-sequence magnetic field generated by the negative-sequence current in the motor produces a braking torque on the rotor, which reduces the output of the motor, which may cause additional heating of the motor, and even burn the motor in severe cases.

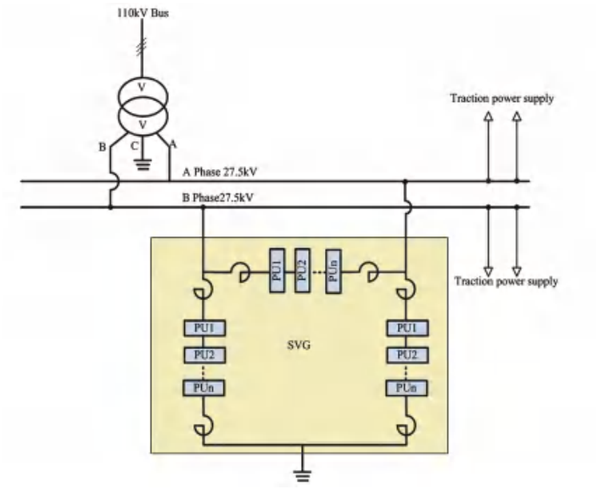
RXPE Solution

Transformers used in traction substations mainly include V/V transformers and Scott junction transformers.

The phase difference of the secondary winding of Scott transformer is 90 degrees, which can reduce the influence of negative sequence current, but the transformer wiring is complicated and costly.

The V/V transformer connects two single-phase transformers to the three-phase power system in the form of V. Each traction substation can be powered by the two-phase line voltage of the three-phase system. As to the two secondary windings of the transformers, we take one terminal from each of them, and connect them to two-phase busbars of the traction substation. While the other terminals can be connected together in the form of common port, and connect it to return cable back from the rail.

The corner joint SVG can be connected to the secondary side of the V/V traction transformer. The two bridge arms of the corner joint SVG are connected to AN and BN respectively, and the third bridge arm is connected between AB, as shown in the following figure. The phase difference of the terminal voltages of the three SVG bridge arms is 120 degrees, so the principle of Stemitz balance compensation can be used to compensate for the negative sequence current in the load.



System wiring diagram (SVG installed on the secondary side of the traction transformer)

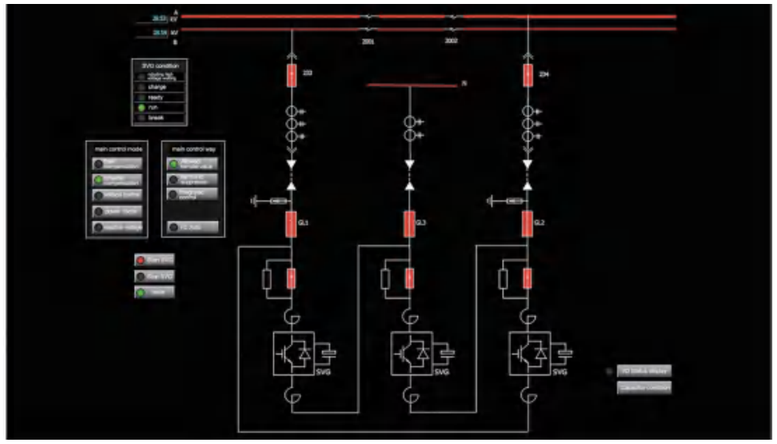
RXPE provides a set of 18Mvar SVG for the Liujiagou traction converter station of Shenshuo Railway, which is used to control the unbalanced load of the railway 27.5kV system. At the same time, it adopts active filter technology to filter out the harmonics generated by the load.

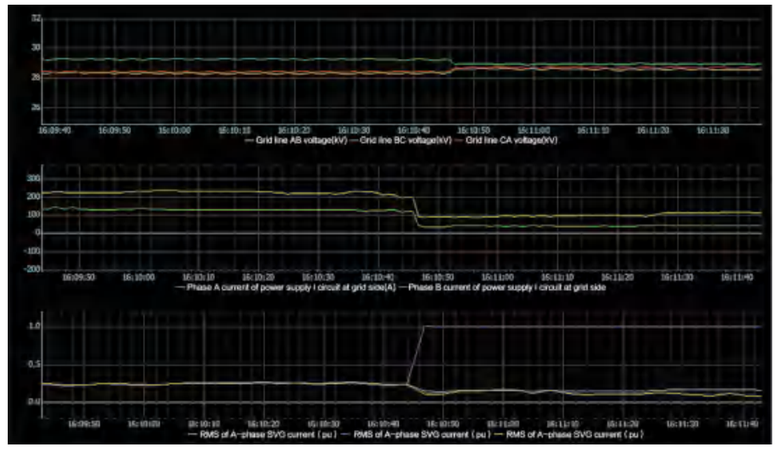
Photos of project on site 1

Photos of project on site 2

Customer Benefits

After the SVG is put into operation, the on-site power factor is higher than 0.95, and the harmonic current and negative sequence current injected into the power grid are effectively reduced, which meets the relevant standards of the power grid company.





Low-frequency oscillation suppression of high-speed railway traction network

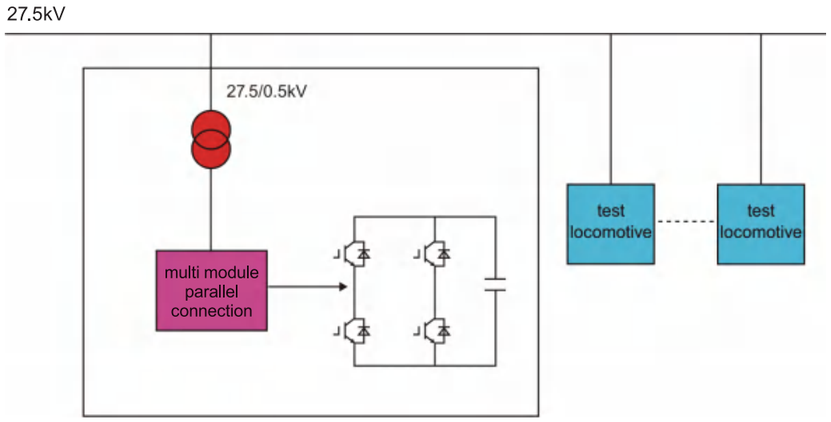
Customer Needs

Bombardier sifang(Qingdao) Transportation Ltd(short for BST), founded in 1998 located in Qingdao city, Shandong province, China. BST is a Sino-foreign equity joint venture company invested by CRRC sifang co., ltd and Bombardier company. The main products of BST are high speed train and bullet train, the BST railway locomotive products are widely used in china and worldwide railway.

But there is a big problem happened at the stage of railway locomotive operation. When more than five railway locomotives are running under the traction power grid at the same time , the grid voltage, grid current and DC voltage will appear a large fluctuation and it leads to low frequency oscillation. Finally all the locomotives will face a fault of traction block and causing a large-scale off-stream which will bring a great losses for the railway company.

RXPE Solution

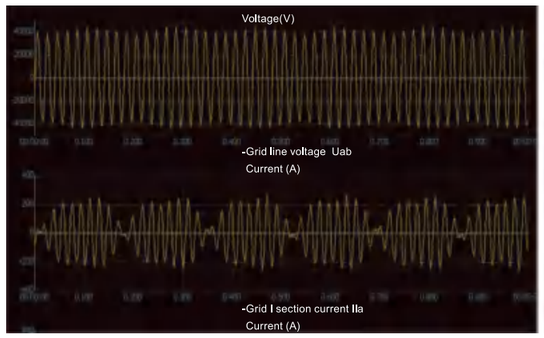
RXPE designed a low frequency oscillation suppressor for the customer and its topology picture is as below:



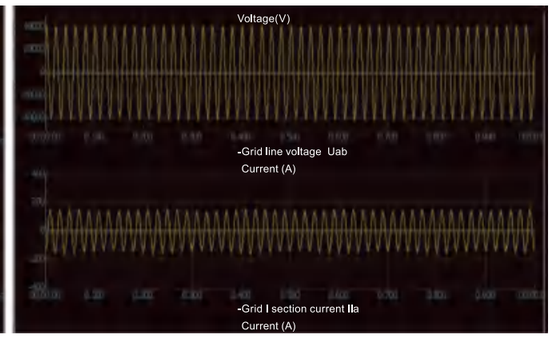
Low frequency oscillation suppressor

Supply electricity to multiple module units through 27.5/0.5kV step-down transformer. Through the inspection of load harmonic current , the controller will make the module imposing the harmonic current which has the same current amplitude and opposite phase with load harmonic current. This movement will depress the load side harmonic current and then restrain the low frequency of locomotive.

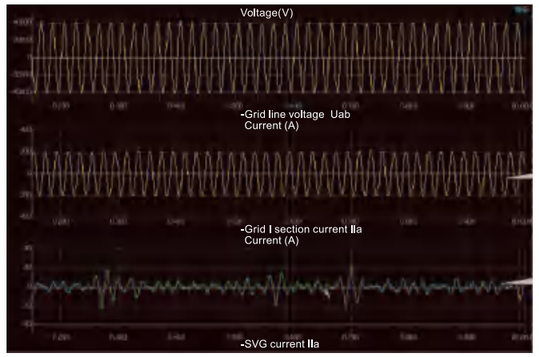
Below is a voltage and current waveform comparison between using suppressor and without suppressor when eight locomotives operate simtaneously.



Without low frequency oscillation suppressor



With low frequency oscillation suppressor



The waveform when 13 locomotives operate at the sametime
(with low frequency oscillation suppressor)

Customer Benefits

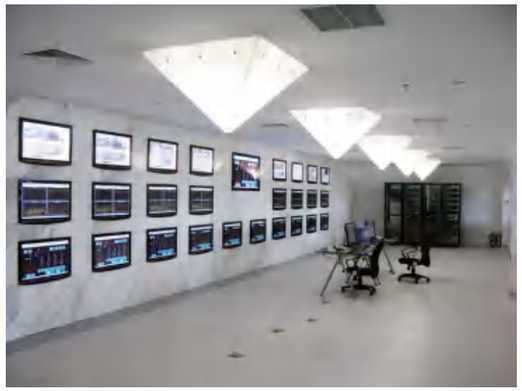
With the using of low frequency oscillation suppressor, it will stabilize the grid voltage and current , dismissing the low frequency oscillation. The span life of locomotive and other load equipment will be increased. The customer will not concern about the economical losses caused by locomotive off-stream any more.

After-sale Service

- Provide full range of services for professional testing, training, equipment maintenance, product upgrade, repair and replacement , spare parts sales, etc.

- Professional customer service team, 7 days a week, 24 hours a day of service, for domestic users promises to arrive at the site in 24 hours, to solve the problem in 48 hours.

- Advanced remote supervision system, 24 hours global online, diagnosis, parameter adjusting, trouble shooting service for our customers.



Global Reference