The design and application of comprehensive experimental platform for custom power equipment

Yeniu Qian[a], Jian Sun, Yan Zhang and Dongqiang Jia

State Grid Beijing Electric Power Research Institute, 100075 Fengtai, Beijing, China

Abstract. The Comprehensive Experimental Platform for Custom Power Equipment is designed based on voltage source power quality disturbance device, current source power quality disturbance device and phase shifter. Actual operating performance of Solid State Transfer Switch, Dynamic Voltage Restorer and Flywheel Energy Storage Device are experimentally analysed by the experimental platform. The experimental platform has the advantage of functional, flexible and expansion. In addition, The Experimental Platform Can be used to study factory experiment, handover experiment and maintenance technology of Active Power Filter, Static Synchronous Compensator and so on.

Keywords: solid state transfer switch; dynamic voltage restorer; flywheel energy storage device; custom power.

1 Introduction

With the rapid development of modern science and technology, nonlinear load and impact load are widely used by terminal user .Distribution network power quality are contaminated seriously and destroyed. In addition, the control equipment and electrical device based on Microprocessor and Microcomputer appear in mass.For example, frequency conversion equipment, programmable controller, precision CNC machine and information management system are widely used in bank ,data center , precision machine process and semiconductor manufacturing ,result in power system power quality sensitively. Especially, voltage dips not only affects user's production ,but also bring about severe economic loss directly or indirectly. So it is imminent to improve distribution network power quality.

For the distribution system power quality problems, relying on modern power electronics and control technology, custom power technology emerges. The so-called custom power technology, also known as user power technology, proposed by Palo Alto firstly, the expert of American Electric Power Research Institute, has been rapid developed and applied all over the world. It is mainly based on high-power electronic switching devices, and adopts microprocessor, optical fiber communication, digital signals processing power electronic controller is used for1-38kV distribution network to provide the reliability and better power quality which meet users requirements. custom power technology can provide 'needed power' for users, even users are strict to power quality. Controller adopting custom power technology is called custom power equipment. such as Solid State Transfer Switch(SSTS), Dynamic Voltage Restorer(DVR), Active Power Filter(APF), Static Synchronous

[a] Corresponding author : gotoqianyeniu@163.com.

Compensator(STATCOM), Unified Power Quality Conditioner(UPQC) ,Flywheel Energy Storage Device(FESD) and so on.

It is early to study the custom power technology abroad,and there are some outstanding achievement. Custom power equipment is in piloting application stage in domestic. Product's functional and performance is lack of complex long-running test. Custom power equipment's experimental study with different characteristic loads is not enough in various conditions. The best performance of custom power equipment is affected easily by various factors, the actual operating performance, high power quality and high reliability to sensitive loads are determined by experimental study. The comprehensive Experimental Platform is designed and experimental study is operated to improve the ability about study and detecting.

2 Custom power equipment introduction

There are typical custom power equipment in distribution network, such as SSTS, DVR, APF, STATCOM, FESD ,UPQC and so on. Now, we will introduce some important equipment from these custom power equipment.

2.1 SSTS introduction

SSTS consist of parallel fast switches PS1 and PS2, anti-parallel thyristor switches TS1 and TS2, power load's switches Q0, Q1, Q2. it's basic structure is shown in figure-1.

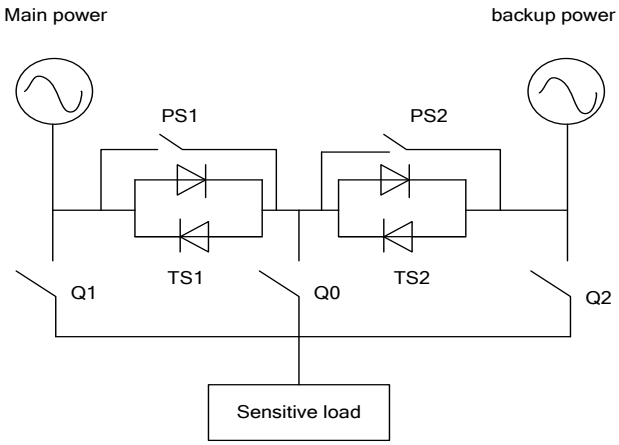

Figure 1. SSTS structure diagram

Main power supplies power for load, the parallel high speed mechanical switch PS1 is turned on. Thyristor switch TS1 is bypassed, Power switch Q0 is turned on. SSTS control system sends switch order, PS1 is turned off, TS1 is turned on,when main power voltage occurs an exception . Current is shifted to thyristor immediately. There is little arc, if not , arc will be snubbed out because of thyristor's turning on when PS1 is turned on. Thyristor will be turned off when current cross 0 firstly at the condition that TS1's trigger signal has been withdrew.Then TS2 is turned on and supplied by backup power. At this time, the switch has been completed. After a period of time to be stabilized ,the control system send order to turn on PS2, TS2 is in the state of turn on and the voltage is closed to 0. the arc will not be generated when PS2 is turned on .when SSTS need to be maintained ,load is supplied uninterruptedly by power switch Q1 and Q2. SSTS implements two incoming feeder's millisecond switch, voltage dips and short-term power interruption can be solved. User's loss is reduced to ensure reality power supply.

2.2 DVR introduction

DVR consist of energy storage unit, DC voltage stabilization unit, fully - controlled inverter and series transformer, it's basic structure is shown in figure -2. DVR is connected between power grid and sensitive loads. when the distribution network is normal, device's energy loss is little. Load voltage can be compensated by DVR in millisecond when power grid voltage dips signal is detected by system .Sensitive load voltage can be restored to normal value. DVR is in standby state to make sensitive load's voltage reliability. Because DVR only compensate the part of voltage dips shortfall, it is known as effective device to ensure high voltage quality for sensitive load and it is very useful in eliminating voltage dips, enhancing power quality for big sensitive industrial load.

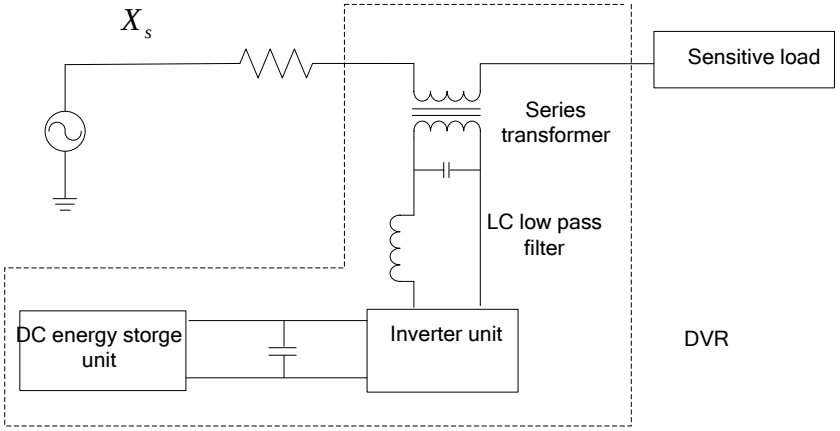

Figure 2. DVR structure diagram

2.3 APF introduction

APF is a new electronic power electronic device to dynamic control harmonic and compensate reactive power. It can detect harmonic current from harmonic source load and generate an equal and opposite direction harmonic current to restrain harmonic current to flow into power grid. The advantages of APF are fast dynamic response, more compensation function and its characteristic is not affected by power grid parameter, so it has been widely studied and applied all over the world. There are many types of APF, in fact voltage-shunt APF is widely used in AC power system. Its structure is shown in figure-3.

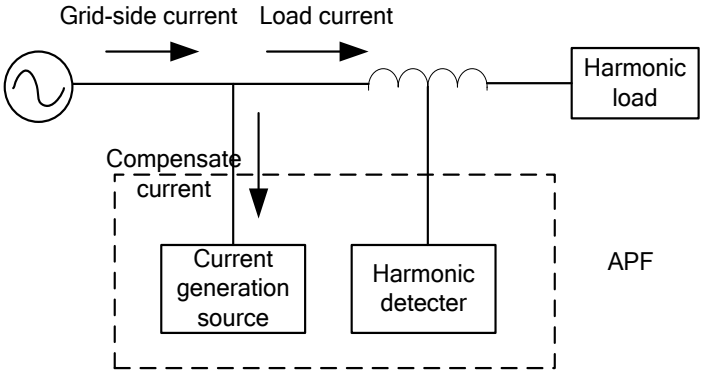

Figure 3. APF structure diagram

2.4 STATCOM introduction

The basic principle of STATCOM is that three-phase bridge converter circuit is installed on load side bus in parallel, then the amplitude and phase of three-phase bridge circuit's output voltage and current are adjusted. Then satisfied reactive current is absorbed or generated to dynamic compensate reactive power. According to the different energy storage device on DC side, STATCOM can be classified voltage – STATCOM and current- STATCOM. The structure of normal voltage-mode STATCOM is shown in figure-4.

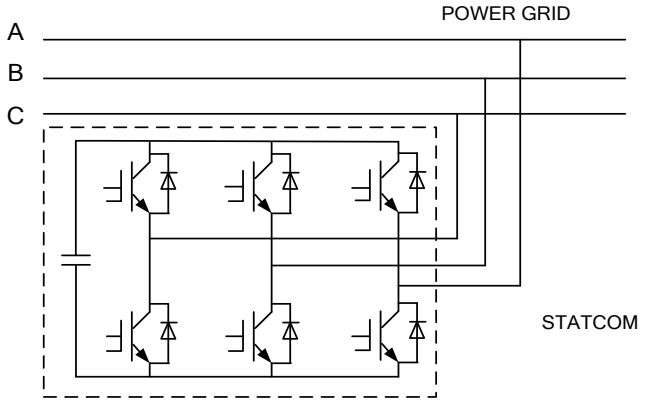

Figure 4. STATCOM structure diagram

2.5 FESD introduction

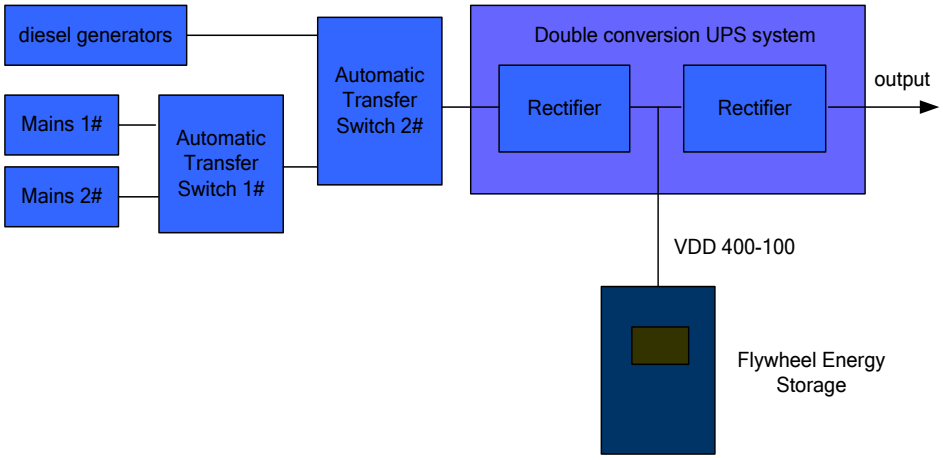

Figure 5. FESD structure diagram

The structure of FESD is shown in figue-5. AC is transformed to DC when it is pass the rectifier. Internal DC is responsible for the Flywheel energy storage and supplies power for inverter. DC is inversed to high quality AC for load by inverter. Sometimes three source input is adopted to Maximum increase power reliability,although it's a redundancy pattern. From mains#1 to mains#2 and then diesel generators is set.

When input mains break down,FESD releases energy supplies power for inverter so that high quality AC is supplied to load by inverter, at same time diesel generators is started in 6-8 second and energy is transported to rectifier. diesel generators continues to run for a period of time when mains

recovery. Diesel generators can run 8 hours at least in the case of mains interruption, because it is equipped with a fuel tank.

3 The design and achievement of Comprehensive Experimental Platform for Custom Power Equipment

According to custom power equipment various structure, the ways of joining the lines of Comprehensive Experimental Platform for Custom Power Equipment is shown in figure-6. There are three kinds of power quality disturbance device connected to experiment platform such as voltage-mode power quality disturbances device ,current-mode power quality disturbance device, phase shifter, their parameter is shown in table-1to table-3.others is shown in table-4. Power switches located in Experimental Platform are installed in a distribution Cabinet to operating flexible operating. In addition , all custom power equipment are connected to the power switches utilizing quick connector and dedicated soft cable to improve the flexibility of platform. Different types of custom power equipment testing are achieved through different combination of power switch.

1) SSTS TEST: turn on QF1, QE3, QF7, QF2, QF4, QF8, QF9, QF11, QF13, QF17, QF18. Set phase shifter. Prove the affection of different power supplies to SSTS's switching time.Set voltage-mode power quality disturbance device, test SSTS response time ,voltage dips and mains interruption treatment effect.

2) DVR TEST: turn on QF1, QF3, QF7, QF9,SSTS bypass repairing switch,QF13, QF15, QF16, QF18. Set voltage-mode power quality disturbance device, test DVR response time and Voltage dips treatment effect.

3) APF TEST: turn on QF1, QF5, QF9,SSTS bypass repairing switch,QF13, QF17, QF19, QF21. Set current-mode power quality disturbance device, test APF response time and filter effect.

4) STATCOM test : turn on QF1, QF5, QF9,SSTS bypass repairing switch,QF13, QF17, QF18, QF20. Set loads with different power factor , test STATACOM response time and power factor improving effect.

5) FESD test: turn on QF1, QF3, QF7,QF2, QF4,QF8,QF10,QF12,QF14,QF17,QF18.Set phase shifter. Prove the affection of different power supplies to FESD's switching time. Set voltage-mode power quality disturbance device, test FESD response time, voltage dips and power supply discontinue managing effect.

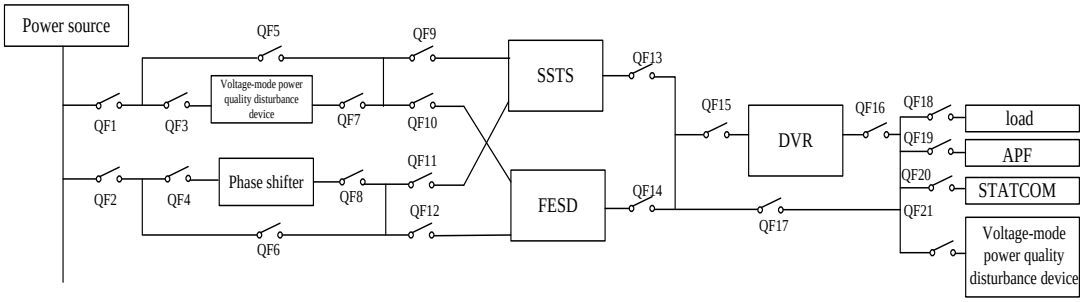

Figure 6. Wiring Diagram of Comprehensive Experimental Platform for Custom Power Equipment

Table 1. Voltage-mode power quality disturbances device parameter

rated voltage	AC380V±10%
rated frequency	47~63Hz
connecting method	three-phase four-wire system
Swells amplitude	110%-140%
Dips amplitude	0%-90%
Swells dips set	Three-phase simultaneously set ,split phase set, initial phase angle of swells and dips set ,duration of swells and dips set. Initial phase angle range from 0 to 360, 1degree step, duration continue any time ,1 ms step.,1 V step of swells and dips, Switching time of swells and dips less 100 μs.
Rated Capacity	90kVA
Output voltage harmonic frequency	2-50 ,single or Any combination of harmonic

Table 2. Current-mode power quality disturbances device parameter

rated voltage	AC400V±15%
rated frequency	50Hz
Connecting method	three-phase four-wire system
Rated Capacity	RMS<100A
Output harmonic current	Three phase or single phase and balance or Unbalance harmonic current, single output harmonic current<100A
Output harmonic order	2-50 , single or Any combination of harmonic
Instantaneous response time	<100us
three-phase output Unbalance	Three-phase independent control, generate single harmonic

Table 3. Phase shifter technology parameter

Rated voltage	AC380V±10%
Rated frequency	50Hz
Connecting method	three-phase three -wire system
Phase shift range	0-45°
Phase shift step	1°
Rated current	45A

Table 4. Other device technology parameter

SSTS	Rated current 300A, rated voltage AC380V, three-phase four-wire system ,switching with earth wire
FESD	rated voltage AC380V, rated power 250kVA, energy storage switching time <2ms, DC bus voltage<400-700V.
DVR	Rated voltage AC380V,response time<2ms, rated current 50A, three-phase four-wire system
APF	Rated voltage AC380V, Rated compensate capacity 60A, effective filter response time <10ms, switching frequency 20kHz.
STATCOM	Rated voltage AC380V, Rated compensate capacity 200kVar, total response time<10ms, switching frequency 15kHz.

4 Application of comprehensive experimental platform for custom power equipment

The test results of SSTS,DVR and FESD is shown by different switch combination for different topology structure custom power equipment testing.

4.1 SSTS testing

Voltage-mode power quality disturbance device is set, three phase voltage reduce to 60 percentage, last for 60 ms, initial phase angle 90°, set phase shifting angle 15°. Load is 250W metal-halide lamp. Testing wave is shown in figure-7. Deep-yellow wave symbols C-phase voltage at QF11, green wave symbols C-phase voltage at QF9, Red wave symbols C-phase voltage at QF13. from fugure-7. we know that switching time of SSTS is 12.3 ms. Metal-halide lamp flicks quickly in testing ,its light has not been changed and snubbed out.

Figure 7. Experiment results of SSTS switching time

4.2 DVR testing

Voltage-mode power quality disturbance device is set, A-phase and B-phase voltage reduce to 30 percentage, last for 6s, initial phase angle 0, Load is metal-halide lamp. IA=3.3A, IB=2.8A. Testing wave is shown in figure 7 and figure 9. Red wave symbols A-phase voltage at QF15, blue wave symbols A-phase voltage at QF16,from fugure-8 and figure-9 we know that compensating response time of SSTS is 1.69 ms. Its compensating time is 5.06 s.

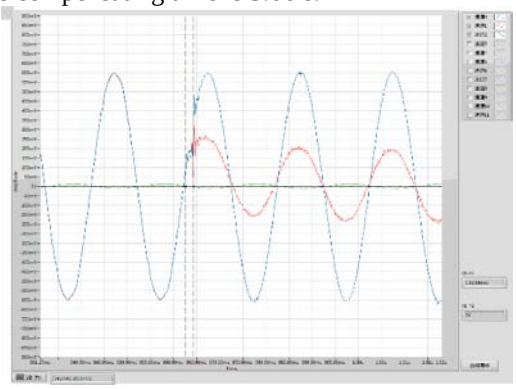

Figure 8. Experiment results of dynamic compensate response time

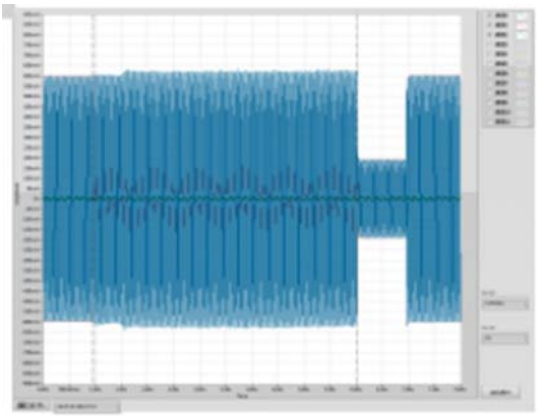

Figure 9. Experiment results of dynamic compensate time

4.3 FESD testing

QF10 is turned off to imitate FESD's power is disconnected. Load is metal-halide lamp. IA=10.9A, IB=12.9A, IC=12.1A. Testing wave is shown in figure-10 and figure-11. figure-10 at QF10, figure-11at QF14. from figure -11,we know that output voltage has a recess in the case of its power is disconnecting .Then it return to normal value after 1.5ms.

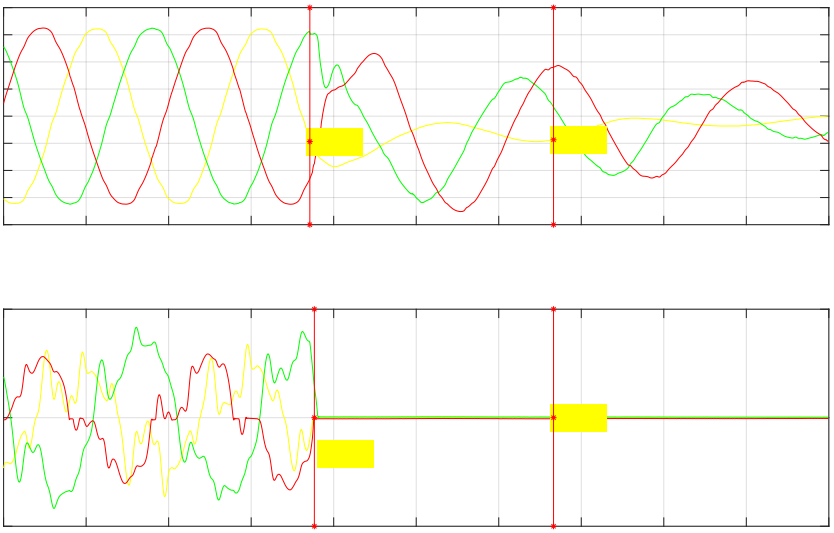

Figure 10. FESD voltage and current wave

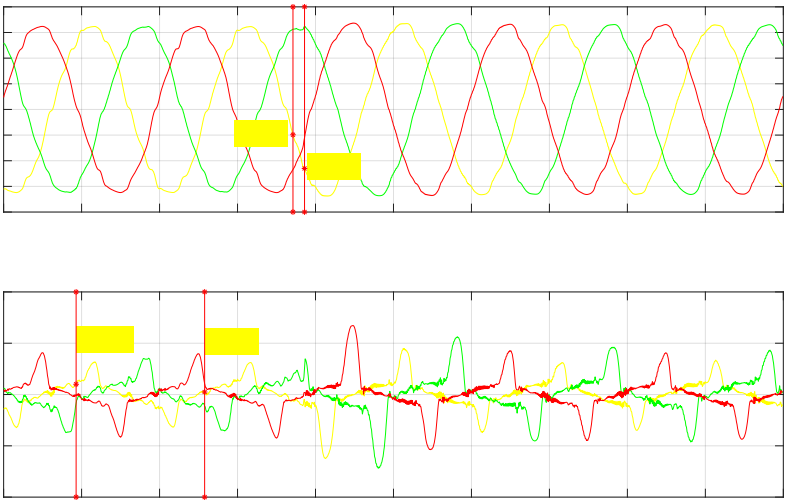

Figure 11. FESD output voltage and current wave

5 Conclusion

The designed Comprehensive Experimental Platform for Custom Power Equipment is mainly integrated five kinds of topologies structure custom power devices and three kinds of power quality disturbance devices.The experimental platform has the advantage of functional, flexible and expansion. It can provides not only test tools for exploring the performance of custom power equipment, but also entire performance verification platform for user custom power solutions, overall testing environment and industrial technical services for Equipment manufacturers and dealers. The testing platform Construction plays a positive role for the application of custom power technology in important users and sensitive users in Beijing .

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