

## THE DESIGN OF PERFORMANCE TEST SYSTEM FOR GRID-CONNECTED PHOTOVOLTAIC INVERTERS

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### ABSTRACT

*Detection platform for grid-connected photovoltaic inverters (PVI) is researched and developed; the testing method and procedures of PVI are analyzed and the development course of this detection platform is described in detail. The detection platform consists of PC machine, interface card and a data bus, AC / DC programmable power supply, power meter, RLC adjustable load, simulation of the impedance network and the measured equipment.*

### INTRODUCTION

Since 2006, China has issued a series of policies for supporting photovoltaic power and other renewable energy development. In 2009, the Chinese government issued a "golden sun demonstration project", "national photoelectric building demonstration project" policy. Those policies and measures to stimulate the development of Chinese photovoltaic power generation industry and at the same time also eased the pressure from Europe and the United States "double reverse" survey on China PV industry. In 2011, the growth of installed capacity of photovoltaic generating is 700% year-on-year, and the future of China's total installed capacity of distributed power generation may be reach 15GW. State Grid Corporation of China(SGCC) with "support, welcome, service" service concept supports China's distributed photovoltaic generation project connect to grid, by the year 2012 the capacity photovoltaic power generation has reached 2.71 million kW in business area of SGCC. With the rapid development of distributed photovoltaic power generation, China is to strengthen management and coordination from planning, connecting, design, construction, inspection, operation and maintenance process, and requires that all key part products in the photovoltaic power generation system need pass product quality test.

### 1 THE MAIN STANDARD SPECIFY AND TECHNICAL CONDITION

PVI is one of the important parts in photovoltaic power generation system; it changes the DC electrical energy into AC and supply load through Grid. In view of the importance of PVI, it should own the quality of security, stability, small output waveform distortion and so on. The

product quality will directly affect the safety of the local power grid, and of the user's personal property. Many standard defines the technical conditions of the inverter in global. EN 50530 proposes total efficiency concept for inverter, testing procedures of conversion efficiency, MPPT tracking efficiency and other technical conditions. VDE-0126 Automatic disconnection device between a generator and the public low voltage grid, IEC 62116 Test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters. VDE-0126 and IEC 62116 set the anti-island protection test methods and steps for grid equipment. IEC 62109 Safety of power converters for use in photovoltaic power systems applies to the power conversion equipment (PCE) for use in Photovoltaic (PV) systems where a uniform technical level with respect to safety is necessary. This standard defines the minimum requirements for the design and manufacture of PCE for protection against electric shock, energy, fire, mechanical and other hazards. One of series standards refer to China Gold Solar Demonstration Project, CNCA/CTS0004-2009A Technical Specification of Grid-connected PV inverter defines the testing procedure of electric performance, protection function and electromagnetic compatibility (EMC) and so on. IEC 62109 applies to the power conversion equipment (PCE) for use in Photovoltaic (PV) systems where a uniform technical level with respect to safety is necessary. The standard defines the minimum requirements for the design and manufacture of PCE for protection against electric shock, energy, fire, mechanical and other hazards. One of series standards refer to China Gold Solar Demonstration Project, CNCA/CTS0004-2009A defines the testing procedure of electric performance, protection function and electromagnetic compatibility (EMC) and so on.

### 2 DETECTION PLATFORM MAIN FUNCTION AND STRUCTURE

#### 2.1 Detection platform main function

Electric performance test, protection function test, EMC test and other test consist of the main function of the detection platform.

#### 2.2 Detection platform structure

The detection platform consists of PC machine, interface card and a data bus, AC / DC programmable power supply, power meter, RLC adjustable load, simulation of

the impedance network and grid simulator, which is shown in Fig.1. In this platform a PC computer is used as host machine, and equipment as client machine and the interface of client machine have GPIB interface and RS 485 interface. The system makes use of programmable DC source as solar simulator. With constant voltage, constant current and constant power operating modes, the solar simulator can simulate the volt-ampere characteristics curve of photovoltaic battery. Programmable AC power source used as grid simulation can simulate the voltage fluctuation and flicker, voltage swell and sag, voltage and frequency variation, the voltage harmonics and three-phase unbalanced and many other kinds of power change. PC computer use RS485 bus to control RLC adjustable load and control switch, and then achieve the automatic switching of switch and the automatic adjustment of load. PC computer use GPIB bus to control DC source, AC power source, power analyzer, waveform recorder and so on, and realize AC/DC power source programmable control, automatic data acquisition and analysis, waveform records and other functions. The whole detection system is controlled by LabVIEW software interface to achieve the electric performance testing of grid—connected photovoltaic inverters, testing of protection function, testing of electromagnetic compatibility (EMC) and so on. The maximum test power capacity of the detection platform is 30kW.

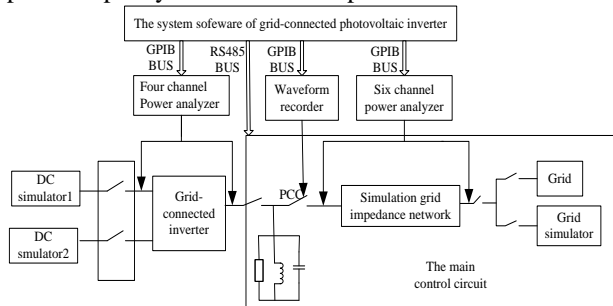


Fig.1 Hardware block of photovoltaic inverter test system

### 2.3 Conversion efficiency test

#### 2.3.1 Test requirements

To improve the utilization ratio of energy, we should try our best to improve the conversion efficiency of PVI. The conversion efficiency of PVI Should be measuring at load point of 5%, 10%, 15%, 20%, 25%, 30%, 50%, 75%, 100% and maximum output point. For the PVI without transformer type the maximum conversion efficiency should be not less than 96% and for contain transformer type not less than 94%.

#### 2.3.2 Test method

This function can realize automatic test through the program control. Set the DC source output and MPPT curve parameters; make the maximum power point output meet requirements of test load point. This adjustment process is controlled by the PID algorithm automatically, as figure2. The conversion efficiency are defined as

EN50530, measuring process generally take  $T_m = 10$  min, taking measurement data per 1 minute, take 10 point efficiency of the arithmetic mean value. The system has tested a PVI of Danfoss (12kW, three-phase), the connection mode show as figure1, and one time test result as below.

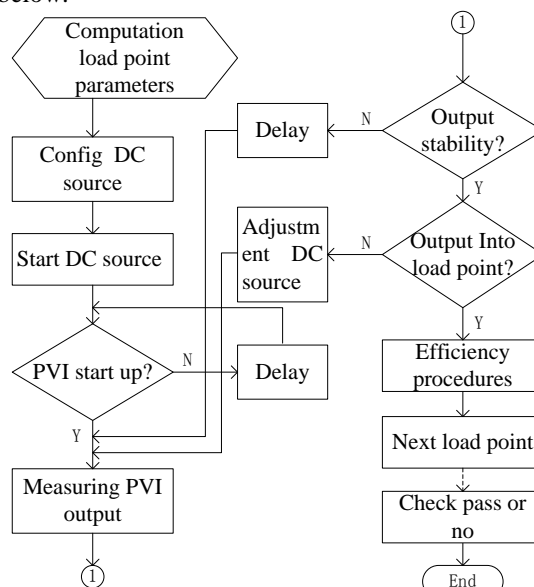


Fig.2 Conversion efficiency test procedures

Table 1 Conversion efficiency test results(one time sample data)

	DC (CH1)	L1 (CH2)	L2 (CH3)	L3 (CH4)	SUM (CH2-4)
U(V)	544.6	232.7	232.4	232.2	/
I(A)	23.72	17.47	17.46	17.50	/
P(W)	12915	4059	4051	4057	12167
S(VA)	/	4067.9 2	4059.1 0	4064.7 8	12191
Q(var)	/	260.31	252.59	250.20	763.10
PF	/	0.998	0.998	0.998	0.998
$\eta$ (%)	94.21				

### 2.4 Harmonic current test

#### 2.4.1 Test requirements

When PVI run at rated power, the injection harmonic current total distortion rate limit is 5%, every harmonic current content limit see table 2. Other load cases operation, PVI injection current value into grid shall not exceed harmonic current value at rated power.

Table 2 Harmonic current limit

Odd harmonic	content (%)	Even harmonic	content (%)
3 <sup>rd</sup> -9 <sup>th</sup>	4.0	2 <sup>nd</sup> -10 <sup>th</sup>	1.0
11 <sup>th</sup> -15 <sup>th</sup>	2.0	12 <sup>th</sup> -16 <sup>th</sup>	0.5
17 <sup>th</sup> -21 <sup>st</sup>	1.5	18 <sup>th</sup> -22 <sup>nd</sup>	0.375

23 <sup>rd</sup> -33 <sup>rd</sup>	0.6	24 <sup>th</sup> -34 <sup>th</sup>	0.15
Above 35 <sup>th</sup>	0.3	Above 36 <sup>th</sup>	0.075

**2.4.2 Test method**

This function can realize automatic test through the program control. The process and principle of load point parameters configuration is same as above. Harmonic measurement procedures generally take 3 times of the measurement result arithmetic mean value, automatic determine whether qualified.

**2.5 Anti-island protection test**

**2.5.1 Test requirements**

PVI should have anti-island protection function. If the grid interrupts power supply, PVI should stop power supply within 2s and output warning signal at the same time. When this function conflict with low voltage tolerance ability, the latter is preferring. According to the VDE - 0126, IEC 62116, the test should be done at 100%, (50 to 66) %, (25 to 33) % load point

**2.5.2 Testing method**

This function can realize automatic test through the program control. The Connection mode is showed as figure1. The process and principle of load point parameters configuration is same as above. Adjusting RLC load for matching PVI output, and making quality factor Q = 1. When the PCC point grid current value of fundamental component less than PVI rated output current 1%, resonance state is reached. The grid is switched off at the moment, using oscillograph recording PVI anti-island function action process and action time, principle as the figure 3.

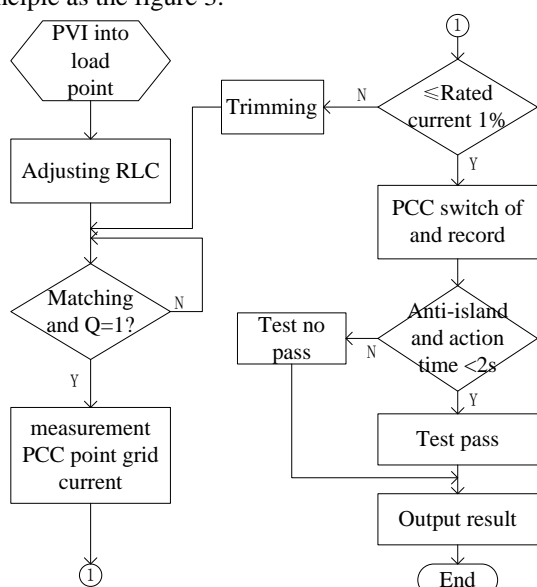


Fig.3 Anti-island protection test procedures

**2.6 Grid protection function test**

**2.6.1 Test requirements**

Protection function test item content: Overvoltage/under-voltage protection test, Over/under-frequency protection

test, LVRT protection test, Voltage dips , short interruptions and voltage variations immunity tests. Main specification come from CNCA/CTS0004-2009A, Technical Specification of Grid-connected PV inverter and IEC61000-4-11(china: GB/T17626.11)

**2.6.2 Test method**

Grid simulator is a kind of program power system (type: NF ES18000), and it can output pour sin wave with voltage or frequency variation, meet the test requirement of iec61000-4-11. This function can realize automatic test through the program control. The process and principle of load point parameters configuration is same as above. In protection function test procedure, the configuration of every test item mast write to Grid simulator, and then run to test. Protection function test procedure generally take 3 times of the measurement result arithmetic mean value, automatic determine whether qualified.

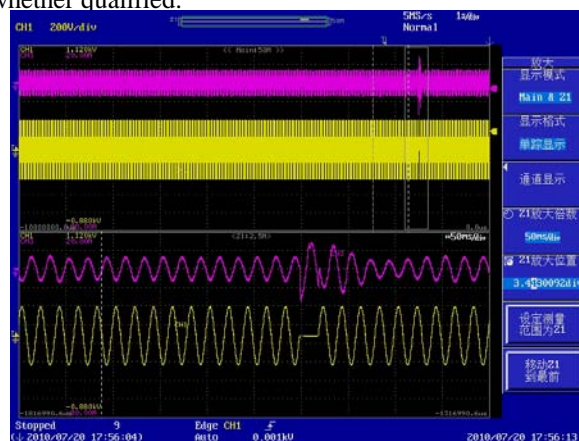


Fig.4 Voltage dips, short interruptions test (0%, 20ms)

**2.7 Other detection items and methods**

Other test such as electromagnetic compatibility test and insulation pressure performance test need to manually completed, test platform temporarily unable to realize automatic test.

**CONCLUSIONS**

This detection platform’s automation degree is higher, and its accuracy is better, which has improved the detection efficiency to a great extent, but this detection platform only has 30kW detection capability, and which only adapt to miniature inverter detection. MPPT test specified by EN50530 cannot be not test in this platform and the MPPT test software is been debugging. Otherwise, one of this detection platform’s technical difficulty is which has solved the difficulty of waveform data’s identify and time interception, which has improved the calculating time precision and automation degree to the events such as protecting action time in protection

function detection.

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