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巴基斯坦默蒂亚里-拉合尔±660高压直流输电工程

系统调试方案

（6）双极大功率系统调试方案

Matiari-Lahore ±660kV HVDC Transmission Project

Commissioning Tests

(6) Bipole High Power System Tests Program

China Electric Power Research Institute

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内容摘要

巴基斯坦默蒂亚里-拉合尔高压直流输电工程双极大功率系统调试方案内容包括：双极功率升降，热运行试验，特殊测量试验。其中详细列出了每个试验项目内容、步骤及验收标准等。

关键词：巴基斯坦默拉直流；双极大功率系统调试方案；系统调试

ABSTRACT

Bipole High Power System Tests Program for Pakistan Matiari-Lahore ±660kV HVDC Transmission Project includes bipole power ramp, heat run test and special measurements.

KEYWORDS: Pakistan Matiari-Lahore HVDC Project, Bipole High Power System Test Program, System Commissioning

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1 Preconditions

IMPORTANT: The pole power during the tests shall be up to 2000 MW, corresponding to 3030 A. The AC voltage at all the both converter stations including Matiari and LAHORE shall be 505-525kV before and during all tests. The frequency at all the both converter stations shall be 49.5-50.5Hz.

Before starting of high power bipolar transmission tests the following activities must have been completed:

- The low power monopolar tests
- Verify that the cooling equipment for converter transformers, smoothing reactor and thyristor valves are operating properly, with the correct switching of fans and pumps. Moreover, it must be checked that the redundant pumps, fans, and heat exchangers are available.
- The thyristor valve cooling pumps are running for more than 24 hours and all air bleeding valves are checked.
- There are four low voltage reactors available in Matiari and two low voltage reactors available at Lahore Converter Station. All are available for manual switching voltage control.

Furthermore, the following pre-conditions apply for all tests defined in this procedure. If any particular pre-condition is necessary for a specific test, it will be added in the test description.

- The test leader from CEPRI and Owner must be appointed.
- All equipment tests and subsystem tests of equipment involved in this test must be completed.
- Low power bipole tests completed
- AC-switchyard and associated protections and sequences, including breaker failure protection, tested
- Verify list of remaining activities and make sure that the test can proceed.

- Verify list of temporary connections and make sure that the test can proceed.
- Verify Sequence of Events Recorder (SER) and make sure no relevant alarms are present and that all systems are operational.
- Prior to each test, select the relevant TFR points that will be recorded, stored, and used as test records.
- All required test equipment available on-site
- The switching sequence prepared by Owner is ready and the station (or all equipment involved in the test) is handed over for operation.

2 Bipole High Power Operation, Normal Power Direction

2.1 Test Objective

The test objective is to carry on heat run test and special measurements during high power test.

2.2 Preconditions

（1）all low power tests have been finished.

（2）AC system precondition:

1) The 500kV bus voltage of two AC systems is about 505~525kV.

2）Both sides of AC system are capable to supply the power for the test.

（3）DC system precondition:

Matiari:

[X] Master

[X] SC A Active	[ ] SC B Active
[X] PCP A Active	[ ] PCP B Active
[X] Normal Pow. Dir.	[ ] Reversed Pow. Dir.
[X] With TCOM	[ ] Without TCOM
[X] Power Control	[ ] Current Control
[X] Joint Control	[ ] Separate Control
[X] RPC Auto	[ ] RPC Manual
[X] Q control	[ ] U control
[X] Norm volt.	[ ] Reduced volt.
[X] Ground Return	[ ] Metallic Return

LAHORE:

[ ] Master	
[X] SC A Active	[ ] SC B Active
[X] PCP A Active	[ ] PCP B Active
[X] Normal Pow. Dir.	[ ] Reversed Pow. Dir.
[X] With TCOM	[ ] Without TCOM
[X] Power Control	[ ] Current Control
[X] Joint Control	[ ] Separate Control
[X] RPC Auto	[ ] RPC Manual
[X] Q control	[ ] U control
[X] Norm volt.	[ ] Reduced volt.
[X] Ground Return	[ ] Metallic Return

2.3 Test Content and Procedure

2.3.1 Bipole Power Ramping (with AC and DC harmonic measurements)

（1） Verify bipole stable operation at scheduled power from NPCC.

（2） Ramp the power up to Maximum Available Power at 100MW/min rate in steps of 400MW, with an interval of 2 min with stable operation in between each 400MW increase:

（3） Verify:

1）The reference is fulfilled after ramping in both stations at each power level.

2）Stable operation at each power level.

3）The RPC in both stations connects the appropriate number of filters and shunt banks in line with the technical specification during the ramping process.

4) Record AC harmonic performance and Ieq (DC line) harmonic performance at each 400MW step and the filter banks connected at each measurement point

（4） Ramp the power down to scheduled power from NPCC at 50MW/min rate in steps of 400MW, with an interval of 2 minutes with stable operation in between each 400MW increase:

（5） Initiate a manual switchover from SC/PCPA to SC/PCPB and from SC/PCPB to SC/PCPA while ramp is in progress at both poles in both stations.

（6） Verify:

1) the ramping process is smooth and continuous without transient changes in the power transmitted.

2) the references in both stations are fulfilled after the ramping is completed.

（7） Record and save test data

2.3.2 Heat Run Test at Maximum Available Power (without redundant cooling)

（1） Take valve and transformer redundant cooling equipment out of serviceas described in dispatch procedure.

（2） Keep the pole in operation for at least 2 hours at Maximum Available Power or until stable winding temperature rise is achieved. The following verifications should be carried during this period:

（3） Perform the tests or measurements below:

1) Verify in both stations that the power reference is fulfilled after the ramping is completed. Ramp up in 400MW steps and measure AC and dc harmonic performance at each step. Record the filters in service at each stop.

2) Verify correct measured current and voltage at DC and AC side.

3) Read valve cooling water temperature inlet and outlet (local and remote indications) outdoor ambient Temp and relative humidity continuously, until reasonable stable temperature is reached.

4) Read ambient temperature top oil and winding temperature in converter transformer every 15 minutes for 1.5 hours and every 30 minutes thereafter (local and remote indications) until reasonable stable temperature is reached. Obtain independent confirmation of top oil temperature by reading near top of tank or on return tube using IR temperature device reading at each time step.

5) Read AC-side individual harmonics, D_n, total harmonic distortion, D_{eff}, Telephone Harmonic Form Factor, THFF, in Matiari and LAHORE.

6) Read DC-side harmonics and Ieq on dc line in Matiari and LAHORE.

（4） Perform the tests or measurements below:

1) Verify main circuit parameters: firing angles, extinction angles, AC and DC currents and voltages.

2) Read temperatures of valve cooling water, transformer and reactor, and verify the stable operation.

3) Perform special measurements as described in below section 2.3.3-2.3.4 as described in dispatch procedure.

（5） Record and save all data.

2.3.3 Radio Interference Measurements

To check if the radio and television interference generated by the HVDC plant is within the specified limit at the specified locations.

（1） Choose 1 or 2 test places inside the converter stations and about 450m away outside the converter station and carry out the measurement of the interference frequency spectrum.

（2） To measure the frequency spectrum characteristics of radio interference under the outlet line of the ±660 kV valve hall and at 20 m from the outlet line inside the converter station.

（3） Record and save all data.

2.3.4 Audible Noise Check

To check if the audible noise level, generated by the HVDC plant, is within the specified limits at specified locations.

（1） Measurement of Audible noise near the convertor transformer in the converter station.

（2） Measurement of Audible noise along the boundary line outside the converter station.

（3） Measurement of Audible noise in front of the houses near the converter station, if there are houses.

（4） Record and save all data.

2.3.5 Bipole Station Service Power Losses

The aim of this test is to determine the losses of the auxiliary supply under load and no-load conditions. According to the study report, only the critical and essential loads of the equipment supplied are included.

（1） In Ready for Operation status, the loads on the 400V power level are measured within one scheduled time period (for example 2 times measurements in one hour). The measurement results are averaged to get values, which are equivalent losses to the no-load or fixed losses.

（2） When the bipole is in operation at MAP, the loads on the 400V power level are measured within one scheduled time period (for example 2 times measurements in one hour). The measurement results are

averaged to get values.

（3） Record and save all data.

2.3.6 Temperature Measurement With IR-Camera Equipment

（1） Verify by use of IR-camera that the temperature of busbars, clamps conductors, equipment, etc. are acceptable in DC-yard, AC-yard, and valve hall.

（2） Record and save all data.

3 Frequency Limiter Control and Runback Function Test

3.1 Test Objective

The test is to check the basic function of frequency limiter control and runback of DC system.

3.2 Preconditions

（1）All monopole low power tests have been finished.

（2）AC system precondition:

1) The 500kV bus voltage of two AC systems is about 505~525kV or lower.

2）Both sides of AC system are capable to supply the power for the test.

（3）DC system precondition:

Matiari:

[X] Master

[X] SC A Active	[ ] SC B Active
[X] PCP A Active	[ ] PCP B Active
[X] Normal Pow. Dir.	[ ] Reversed Pow. Dir.
[X] With TCOM	[ ] Without TCOM
[X] Power Control	[ ] Current Control

[X] Joint Control [ ] Separate Control

[X] RPC Auto [ ] RPC Manual

[X]Q control [ ] U control

[X] Normal volt. [ ] Reduced volt.

[X] Ground Return [ ] Metallic Return

LAHORE:

[ ] Master

[X] SC A Active [ ] SC B Active

[X] PCP A Active [ ] PCP B Active

[X] Normal Pow. Dir. [ ] Reversed Pow. Dir.

[X] With TCOM [ ] Without TCOM

[X] Power Control [ ] Current Control

[X] Joint Control [ ] Separate Control

[X] RPC Auto [ ] RPC Manual

[X] Q control [ ] U control

[X] Normal volt. [ ] Reduced volt.

[X] Ground Return [ ] Metallic Return

3.3 Test Content and Procedure

3.3.1 Frequency Limiter Control test

（1） Verify :

- Matiari converter station is the “MASTER” station
- pole 1 and pole 2 in Bipolar Power Control Mode respectively.
- bipole power is 1000MW

（2） Verify:

- The DC power corresponding to 1Hz of frequency change is 4000MW.

- Upper and lower output limits of frequency control is 400MW and -250MW.

（3） Simulate the frequency of the AC power grid connected the Matiari station to 50.3Hz and Simulate the frequency of the AC power grid connected the Lahore station to 49.8Hz, and the duration is 4000ms

（4） Verify:

- The DC power ramps up about 400MW. After the frequency deviation disappears, the DC transmission power will automatically return to the value before the test.

（5） Reset the frequency limiter control.

（6） Simulate the frequency of the AC power grid connected the Matiari station to 50.3Hz and Simulate the frequency of the AC power grid connected the Lahore station to 49.6Hz, and the duration is 4000ms

（7） Verify:

- The DC power ramps up about 400MW. After the frequency deviation disappears, the DC transmission power will automatically return to the value before the test.

（8） Reset the frequency limiter control.

（9） Simulate the frequency of the AC power grid connected the Matiari station to 49.6Hz and Simulate the frequency of the AC power grid connected the Lahore station to 50.3 Hz, and the duration is 4000ms

（10） Verify:

- The DC power ramps down about 250MW. After the frequency deviation disappears, the DC transmission power will automatically return to the value before the test.

（11） Reset the frequency limiter control.

（12） Simulate the frequency of the AC power grid connected the Matiari station to 49.3Hz and Simulate the frequency of the AC power grid connected the Lahore station to 50.3 Hz, and the duration is 4000ms

（13） Verify:

- The DC power ramps down about 250MW. After the frequency deviation disappears, the DC transmission power will automatically return to the value before the test.

（14） Record and save all test data

3.3.2 Runback Function test in Lahore Converter Station

（1） Verify :

- Lahore converter station is the “MASTER” station
- pole 1 and pole 2 in Bipolar Power Control Mode respectively.
- bipole power is 1400MW
- Runback Upper output limits is 400MW.

（2） Simulate trip of Lahore Sheikhupura cct. 1 and Lahore Sheikhupura cct. 2 fault in ACSC

（3） Verify:

- The DC power ramps down about 400MW.

（4） Record and save all test data

4 Bipole High Power Operation, Reversed Power Direction (Optional)

4.1 Test Objective

The test objective is to check the AC system response during high power test under reversed power direction.

4.2 Preconditions

（1）all low power tests have been finished.

（2）AC system precondition:

1) The 500kV bus voltage of two AC systems is about 505~525kV.

2）Both sides of AC system are capable to supply the power for the test.

（3）DC system precondition:

Matiari:

[ ] Master

[X] SC A Active	[ ] SC B Active
[X] PCP A Active	[ ] PCP B Active
[ ] Normal Pow. Dir.	[X] Reversed Pow. Dir.
[X] With TCOM	[ ] Without TCOM
[X] Power Control	[ ] Current Control
[X] Joint Control	[ ] Separate Control
[X] RPC Auto	[ ] RPC Manual
[X] Q control	[ ] U control
[X] Norm volt.	[ ] Reduced volt.

[X] Ground Return [ ] Metallic Return

LAHORE:

[X] Master

[X] SC A Active [ ] SC B Active

[X] PCP A Active [ ] PCP B Active

[ ] Normal Pow. Dir. [X] Reversed Pow. Dir.

[X] With TCOM [ ] Without TCOM

[X] Power Control [ ] Current Control

[X] Joint Control [ ] Separate Control

[X] RPC Auto [ ] RPC Manual

[X] Q control [ ] U control

[X] Norm volt. [ ] Reduced volt.

[X] Ground Return [ ] Metallic Return

4.3 Test Content and Procedure

4.3.1 Bipole Power Ramping

（1） Perform breakers and switches in line with the Owner Operation Instructions to bring the converter into a 'Ready for Operation' condition.

（2） Verify both stations in 'Ready for Operation' condition.

（3） Start the bipole at minimum bipole power in Reversed Direction in Lahore, 400MW (303A), ramp rate 100MW/min.

（4） Verify steady performance indicators and stable operation at minimum power.

（5） Ramp the power up to 2000MW at 50MW/min rate in steps of 400MW, with an interval of 2 min with stable operation in between each 400MW increase:

（6） Verify:

1）The reference is fulfilled after ramping in both stations at each power level.

2）Stable operation at each power level.

3）The RPC in both stations connects the appropriate number of filters and shunt banks in line with the technical specification during the ramping process.

（7） Ramp the power down to 400MW at 50MW/min rate in steps of 400MW, with an interval of 2 minutes with stable operation in between each 400MW increase:

（8） Initiate a manual switchover from SC/PCPA to SC/PCPB and from SC/PCPB to SC/PCPA in both poles at both stations while ramp is in progress.

（9） Verify:

1) the ramping process is smooth and continuous without transient changes in the power transmitted.

2) the references in both stations are fulfilled after the ramping is completed.

（10） Stop the pole

（11） Record and save test data

5 Safety measures and special points for the station tests

5.1 For HVDC system

（1） All personnel who take part in the test shall follow all the safety regulations for the electrical works strictly.

（2） In the station a qualified engineer should be appointed as a test leader from the Owner, who shall be a coordinator with CEPRI commissioning engineers.

（3） In the station, qualified technicians from the Owner, the assembly companies or the manufacture companies with mobile phone have to be appointed to watch the equipment in AC yard, in DC yard and in valve hall separately when a test proceeds. They ought to report immediately to the test leader as they find any abnormality or fault of the equipment.

（4） No person can enter into the test area without permission.

（5） All the high voltage area shall be isolated with closed fence and a notice board with ‘HV DANGER!’ should be put on it.

（6） In the station, an emergent maintenance team with mobile phone shall be ready for any repair or inspection work when needed.

（7） Only the personnel with the test identity are allowed to enter the test area.

（8） The qualified operators are only allowed to carry out the operation.

（9） All the operations shall be done strictly according to the Operation Instructions.

（10） The temporary test wiring and maintenance of main circuit equipment in site and control & protection cubicles should be proceeded and corresponding safety measures should be carried out by the qualified personnel under the supervision of qualified specialists.

（11） The test wiring to control or protection cubicles shall be demonstrated and supervised by qualified specialists.

5.2 For AC system

All the regulations and safety measures for the AC system operation have to be followed strictly.

6 Annex

HVDC--High Voltage Direct Current

DC--Direct Current

AC--Alternating Current

CEPRI--China Electric Power Research Institute

TFR --Transient Fault Recorder

PCP--Pole Control & Protection

SCM--SCADA and Monitoring

SC --Station Control

RPC--Reactive Power Control

DGA-- Dissolved Gas Analysis

IR Camera -- Infrared Camera

Dn --Individual Harmonics

THD--Total Harmonic Distortion

THFF--Telephone Harmonic Form Factor

IEQ-- Equivalent Interference Current

MAP - Maximum Available Power

MAP++ - a power transfer the same as or slightly above MAP which may be authorized at NPCC discretion.