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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

（5）单极大功率系统调试方案

Matiari-Lahore ±660kV HVDC Transmission Project

Commissioning Tests

(5) Monopole High Power System Tests Program

China Electric Power Research Institute

2021.04

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4.0	29 Jan 2021	Updated according to OE recommendations about low voltage reactor
5.0	10 Feb. 2021	Updated according to OE comments on A3-A6
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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单极大功率系统调试方案内容包括：极起/停，功率升降，手动分接头控制，大地/金属转换，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；单极大功率系统调试方案；系统调试

ABSTRACT

Monopole High Power System Tests Program for Pakistan Matiari-Lahore ±660kV HVDC Transmission Project includes pole start, power ramp, tap changer control, ground/metallic return transfer, heat run test and special measurements.

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

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1 Preconditions

IMPORTANT: The pole power during the tests shall be up to 2400 MW, corresponding to 3333 A. The AC voltage at all the two converter stations including Matiari and LAHORE shall be 500-530kV before and during all tests. The frequency at all the converter stations shall be 49.5-50.5Hz.

Before starting of monopole high power tests, the following activities must have been completed:

- The low power monopolar tests at normal power direction.
- Verify that the cooling equipment for converter transformers 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 at least two low voltage reactors available in Matiari and two low voltage reactors available at Lahore Converter Station.

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 director from CEPRI and Owner must be appointed.
- All equipment tests and subsystem tests of equipment involved in this test must be completed.
- AC-switchyard and associated protections and sequences, including breaker failure protection, tested
- Final trip test done on each area prior to deblocking.
- 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.
- The switching sequence prepared by Owner is ready and the station (or all equipment involved in the test) is handed over for operation.

2 Pole 1 High Power Test, Normal Power Direction

2.1 Test Objective

The test objective is to check DC equipment performance during high power test.

2.2 Preconditions

（1）all low power tests have been finished at normal power direction.

（2）AC system precondition:

1) The 500kV bus voltage of two AC systems is about 500~530kV.

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 Pole Start

（1） Before start of Heat Run Test, samples for DGA (Dissolved Gas Analysis) shall be taken from all converter transformers of the Pole at both stations.

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

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

（4） Switch RPC to **Q control** in both stations.

（5） Start pole 1 at minimum power in **Normal Power Direction**, **Ground Return Operation,** 200MW (303A), ramp rate 100MW/min.

（6） Record and save all data.

2.3.2 Power Ramp

（1） Verify the pole1 is in monopole power control mode.

（2） Ramp the pole1 power up to 2000MW at 50MW/min rate in steps of 200MW with a stop interval of 2 minutes at the end of each step. The interval is to make sure the system is stable. And manually trigger internal and external TFRs at each power transfer level (every 200MW up to 2200MW) to facilitate Ac side harmonic analysis.

（3） When Ramp pole1 power from 400MW to 600MW at 999MW/min ramp speed.

（4） Verify that the power reaches the reference value after ramping is completed and that the ramping process is smooth and without disturbances.

（5） Initiate in pole 1 a manual switchover from SC/PCPA to SC/PCPB and from SC/PCPB to SC/PCPA while the power ramps from 800MW to 1000MW at both stations.

（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，shunt banks and LV reactors.in line with the technical specification during the ramping process.

（7） Trigger TFR manually to Pole 1 DC side Analogue signal check in controls and Protection, and check the overlap.

（8） Verify both stations in '**Ready for Operation**' condition for pole2.

（9） Start pole2 at minimum power in Normal Power Direction, Ground Return Operation, 200MW (303A), ramp rate 100MW/min after pole 1 power reaches to 2000MW.

（10） Change pole2 from pole power control to bipole power control.

（11） Set bipole power reference is 2200MW

（12） Perform Heat Run Test and Special Measurements See comments to heat run test as described in section 3.3.1 to 3.3.7 below.

（13） Initiate a manual switchover from SC/PCPA to SC/PCPB and from SC/PCPB to SC/PCPA while DC power is 2000MW at both stations.

（14） After 4 hours operation of pole1 with power 2000MW, ramp pole1 power from 2000MW to 2200MW and Set bipole power reference is 2400MW.

（15） Perform Heat Run Test and Special Measurements See comments to heat run test as described in section 3.3.1 to 3.3.7 below.

（16） After 2 hours operation of pole1 with power 2200MW, ramp pole 1 power from 2200MW to 2000MW. Pole2 power will ramp from 200MW to 400MW.

（17） Change pole2 from bipole power control to pole power control. And manually stop pole2.

（18） Perform as Manual Tap Changer Step and Ground/Metallic Return Transfer described in section 2.3.3-2.3.4 at the power level 2000MW.

（19） Ramp the power down to 200MW at 50MW/min rate in steps of 200MW with an interval of 2 min. The interval is to make sure the system is stable.

（20） Initiate a manual switchover from SC/PCPA to SC/PCPB and from SC/PCPB to SC/PCPA while the power ramps from 1600MW to 1400MW at both stations. .

（21） When Ramp power from 800MW to 600MW at 999MW/min ramp speed.

（22） Verify that the power reaches the reference value after ramping is completed and that the ramping process is smooth and without disturbances.

（23） Verify:

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

2) the references are fulfilled after the ramping is completed.

（24） Stop the pole.

（25） Record and save test data.

2.3.3 Tap Changer Control, Manual Tap Changer Step

Notes: This test would be accomplished in parallel with 2.3.2.

Matiari:

（1） Set tap changer control in **MANUAL CONTROL** mode and decrease one steps for decreasing U_{di0}.

（2） Verify decreased firing angle and maintained transmitted current.

（3） Set the tap changer control back to **AUTO CONTROL** mode.

（4） Verify that:

1） The tap changer would automatically return to original position if the AC voltage remained unchanged. And if the firing angle is outside the limit

2） Firing angle back within control limits.

3） Maintained transmitted current.

LAHORE:

（5） Set tap changer control in **MANUAL CONTROL** mode and decrease one steps for decreasing Udi0.

（6） Verify:

1） Decreased DC voltage

2） Maintained gamma (γ) in LAHORE and increased firing angle in MATIARI C/S.

3） Decreased tap position in Matiari to maintain firing angle within control limits.

4） Maintained transmitted current.

（7） Set the tap changer control back to **AUTO CONTROL** mode.

（8） Verify that:

1） The tap changer would automatically return to original position if the AC voltage is unchanged.

2） Firing angle back within control limits.

3） DC voltage back to nominal value.

4） The tap position in Matiari is increased to maintain firing angle within control limits.

5） Maintained transmitted current.

（9） Record and save test data.

2.3.4 Ground/Metallic Return Transfer

Notes: This test would be accomplished in parallel with 2.3.2.

（1） Verify that both stations are in the '**Ready For Ground Return Operation**' condition (in software as well as by visual inspection).

Matiari:

（2） Order **TRANSFER TO METALLIC RETURN**.

（3） Verify:

1) Correct sequential operation of switches and breakers.

2) Correct operation of **MRTB)**in Matiari (The operation of the breaker should be observed visually carefully in order to interrupt the sequence in case of maloperation).

3) No disturbance in power transfer.

4) Check the correctness whether all related switches and breakers in Matiari and LAHORE are correctly operated in line with the technical specification.

（4） Order **TRANSFER TO GROUND RETURN.**

（5） Verify:

1） Correct sequential operation of switches and breakers.

2） No disturbance in power transfer.

3） Correct operation of **GRTS** in Matiari (The operation of the switch should be observed visually carefully in order to interrupt the sequence in case of maloperation).

4） Check the correctness whether all related switches and breakers in Matiari and LAHORE are correctly operated in line with the technical specification.

（6） Record and save all data.

3 Pole 1 Heat Run Test and Special Measurements

3.1 Test Objective

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

3.2 Preconditions

（1）all low power tests have been finished at normal power direction.

（2）AC system precondition:

1) The 500kV bus voltage of two AC systems is about 500~530kV.

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

3.3 Test Content and Procedure

3.3.1 Pole 1 Run at 1.00 p.u. in Monopole without Redundant Cooling

Notes: The procedure would be accomplished in parallel with 2.3.1-2.3.2.

（1） Verify: Pole1 is in normal operation with power 2000MW.

（2） Verify: the Redundant Cooling is out of service.

（3） During pole1 in operation for 4 hours at 1.0 p.u. The following verifications should be carried during this period. If any of the transformers has not reached steady state temperature, then continue for another 1/2 hour.

1) Verify that the measured currents and voltages at DC and AC side are correct.

2) Read, record and plot valve cooling water temperature inlet and outlet (local and/or remote indications) continuously, until reasonable stable temperature is reached (temperatures should be stable within approximately 15 minutes).

3) Read ,record and plot temperature of coil winding and hot spot in converter transformer every 30 minutes until reasonable stable temperature is reached (temperatures should be stable within approximately 3 hours).

4) Read or calculate and record AC-side individual harmonics, D_n, total harmonic distortion, THD, Telephone Harmonic Form Factor, THFF, in Matiari and LAHORE C/S during pole1 power ramping.

5) Read and record DC-side harmonics and Ieq in Matiari andLAHORE C/S from the power quality analyser.

6) Perform special measurements as described in below section 3.3.3-3.3.7.

7) **The Power Loss in Station** should be measured by subtracting the DC power from the power flowing into the converter transformer.

（4） Record and save all data.

3.3.2 Pole 1 Run at 1.1 p.u. in Monopole with Redundant Cooling

Notes: The procedure would be accomplished in parallel with 2.3.2.

（1） Verify: Pole1 is in normal operation with power 2200MW.

（2） During the pole 1 in operation for 2 hours at 1.1 p.u. The following verifications should be carried during this period.

1) Verify that the reference is fulfilled after the ramping is completed.

2) Verify that the measured currents and voltages at DC and AC side are correct.

3) Read, record and plot valve cooling water temperature inlet and outlet (local and/or remote indications) continuously, until reasonable stable temperature is reached (temperatures should be stable within approximately 15 minutes).

4) Read, record and plot temperature of coil winding and hot spot in converter transformer every 30 minutes (local and/or remote indications) until reasonable stable temperature is reached, and record smoothing reactor temperatures with IR camera every 30 min and at end of test.

5) Read and record AC-side individual harmonics, Dn, total harmonic distortion, THD, Telephone Harmonic Form Factor, THFF, in Matiari and LAHORE C/S during pole1 power ramping.

6) Read and record DC-side harmonics and Ieq in Matiari and LAHORE C/S from the power quality analyser.

7) Perform special measurements as described in below section 3.3.3-3.3.7.

（3） Record and save all data.

3.3.3 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.

3.3.4 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.

3.3.5 Station Auxiliary 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 status **Ready for Operation**, the loads on the 400V power level are measured within one scheduled time period (for example 5 times

measurements in one hour) with recording sheets. The measurement results are averaged to get values, which are equivalent losses to the no-load or fixed Auxiliary Power losses.

（2） Verify that these measured loss values are within limited value specified by technical specification.

（3） When the pole 1 is in operation at 1.0 p.u. or 1.1 p.u., the loads on the 400V power level are measured within one scheduled time period (for example 5 times measurements in one hour). The measurement results are averaged to get values.

（4） Record and save all data.

3.3.6 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.

3.3.7 Ground Electrode Test

This test is to be carried out together with Heat Run Test, and it shall be conducted in both electrode sites simultaneously.

（1） Ground Electrode Test refers to《Ground Electrode Test procedure》 .

4 Pole 2 High Power Test, Normal Power Direction

4.1 Test Objective

The test objective is to check DC equipment performance during high power test.

4.2 Preconditions

（1）all low power tests have been finished at normal power direction.

（2）AC system precondition:

1) The 500kV bus voltage of two AC systems is about 500~530kV.

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

[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:

[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

4.3 Test Content and Procedure

4.3.1 Pole Start

（1） Before start of Heat Run Test, samples for DGA (Dissolved Gas Analysis) shall be taken from all converter transformers in the pole at both stations.

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

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

（4） According the actual situation and test requirement, verify the DC configuration is GROUND RETURN(GR).

（5） Switch RPC to **Q control** in both stations.

（6） Start the pole2 at minimum power in **Normal Power Direction**, **GROUND Return Operation,** 200MW (303A), ramp rate 100MW/min.

（7） Record and save all data.

4.3.2 Power Ramp

（1） Verify the pole2 is in monopole power control mode.

（2） Ramp the pole2 power up to 2000MW at 50MW/min rate in steps of 200MW with a stop interval of 2 minutes at the end of each step. The interval is to make sure the system is stable. And manually trigger internal and external TFRs at each power transfer level (every 200MW up to 2200MW) to facilitate Ac side harmonic analysis.

（3） When Ramp pole2 power from 400MW to 600MW at 999MW/min ramp speed.

（4） Verify that the power reaches the reference value after ramping is completed and that the ramping process is smooth and without disturbances.

（5） Initiate in pole 2 a manual switchover from SC/PCPA to SC/PCPB and from SC/PCPB to SC/PCPA while the power ramps from 800MW to 1000MW at both stations.

（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，shunt banks and LV reactors in line with the technical specification during the ramping process.

（7） Trigger TFR manually to Pole 2 DC side Analogue signal check in controls and Protection and check the overlap.

（8） Verify both stations in '**Ready for Operation**' condition for pole1.

（9） Start pole1 at minimum power in Normal Power Direction, Ground Return Operation, 200MW (303A), ramp rate 100MW/min after pole2 power reaches to 2000MW.

（10） Change pole1 from pole power control to bipole power control.

（11） Set bipole power reference is 2200MW

（12） Perform Heat Run Test and Special Measurements See comments to heat run test as described in section 5.3.1 to 5.3.6 below.

（13） Initiate a manual switchover from SC/PCPA to SC/PCPB and from SC/PCPB to SC/PCPA while DC power is 2000MW at both stations.

（14） After 4 hours operation of pole2 with power 2000MW, Perform as Manual Tap Changer Step described in section 4.3.3 at the power level 2000MW.

(15) After 4 hours operation of pole2 with power 2000MW, ramp pole2 power from 2000MW to 2200MW and Set bipole power reference is 2400MW.

(16) Perform Heat Run Test and Special Measurements See comments to heat run test as described in section 5.3.3 to 5.3.6 below.

(17) After 2 hours operation of Pole 2 with power 2200MW, ramp pole 2 power from 2200MW to 1200MW with ramp rate 200MW/Min. Pole 1 will automatically ramp up to 1200MW as it is in bipole power control mode.

(18) Change pole2 control mode from monopole power control to bipole power control and ramp bipole power from 2400MW to 2200MW with ramp rate 50MW/Min.

(19) In Matiari CS, push the button "ESOF" to block pole2.

(20) Verify:

1) DC Power of Pole2 is transferred to pole1 successfully

2) Pole 1 keeps steady operation at 2200MW (1100MW transfer from P2).

(21) Change pole1 control mode from bipole power control to pole power control and ramp pole1 power from 2200MW to 2000MW with ramp rate 50MW/Min.

(22) Apply a +0.08 p.u. step in power order with duration 1000ms in active system from PCP.

(23) Record the power response and the overshoot.

(24) Apply a -0.08 p.u. step in power order with duration 1000ms in active system from PCP.

(25) Record the power response and the overshoot.

(26) Change pole1 control mode from pole power control to pole current control

(27) Apply a +0.08 p.u. step in current order with the duration of 1000 ms in active PCP system by executing the following actions:

(28) Record the power response and the overshoot.

（29） Apply a -0.08 p.u. step in current order with the duration of 1000 ms in active PCP system by executing the following actions:

（30） Record the power response and the overshoot.

（31） Change pole1 control mode from pole current control to pole power control

（32） Matiari C/S Orders **RPC MANUAL.**

（33） Switch off one sub-bank BP11/13 manually.

（34） Verify: one sub-bank BP11/13 is Switched off

（35） Matiari C/S Orders **RPC AUTO.**

（36） Verify: one sub-bank BP11/13 is Switched in.

（37） Lahore C/S Orders **RPC MANUAL.**

（38） Switch off one sub-bank BP12/24 manually.

（39） Verify: one sub-bank BP12/24 is Switched off

（40） Lahore C/S Orders **RPC AUTO.**

（41） Verify: one sub-bank BP12/24 is Switched in.

（42） ramp pole1 power from 2000MW to 1400MW with ramp rate 50MW/Min.

（43） Initiate a manual switchover from SC/PCPA to SC/PCPB and from SC/PCPB to SC/PCPA while the power ramps from 1600MW to 1400MW at both stations.

（44） Lahore C/S manually Orders REDUCED VOLTAGE (70% of nominal voltage).

（45） Verify that the DC voltage is ramping down to reduced voltage without change in power.

（46） Lahore C/S Orders Order NORMAL VOLTAGE.

（47） Verify that the DC voltage is ramping up to normal voltage without change in power.

（48） Set REDUCED VOLTAGE from the DC-line Protection (70% of nominal voltage) by simulating DC line fault by executing the following actions:

1) In **Lahore/PCP/CPU3/C06_CONV_CONTORL/Page 18** software page, change UDSETTING/X1 from '**1.0**' to '**0.7**'.

2) In **Matiari/PCP/CPU3/C06_CONV_CONTORL/Page 11** software page, change TEST_DCLF30/I2 from '0' to '1'.

（49） Verify that there is DC line deionization sequence with recovery to 70% DC voltage on first attempt.

（50） Verify that the voltage is sharply ramping down to the reduced voltage without change in power.

（51） Change all the modified settings back to original value, verify no change in dc voltage.

（52） Lahore C/S Orders Order NORMAL VOLTAGE.

（53） Verify that the DC voltage is ramping up to normal voltage without change in power.

（54） Ramp the power down to 200MW at 50MW/min rate in steps of 200MW with an interval of 2 min. The interval is to make sure the system is stable.

（55） When Ramp power from 800MW to 600MW at 999MW/min ramp speed.

（56） Verify that the power reaches the reference value after ramping is completed and that the ramping process is smooth and without disturbances.

（57） Verify:

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

2) the references are fulfilled after the ramping is completed.

（58） Stop the pole1.

（59） Record and save test data.

4.3.3 Tap Changer Control, Manual Tap Changer Step

Notes: This test would be accomplished in parallel with 4.3.2.

Matiari:

（1） Set tap changer control in MANUAL CONTROL mode and decrease one steps for decreasing Udi0.

（2） Verify decreased firing angle and maintained transmitted current.

（3） Set the tap changer control back to **AUTO CONTROL** mode.

（4） Verify that:

1） The tap changer would automatically return to original position if the AC voltage remained unchanged, and if the firing angle is outside the limit.

2） Firing angle back within control limits.

3） Maintained transmitted current.

LAHORE:

（5） Set tap changer control in **MANUAL CONTROL** mode and decrease one steps for decreasing Udi0.

（6） Verify:

1） Decreased DC voltage

2） Maintained gamma (γ) in LAHORE increased firing angle in MATIARI C/S.

3） Decreased tap position in Matiari to maintain firing angle within control limits.

4） Maintained transmitted current.

（7） Set the tap changer control back to **AUTO CONTROL** mode.

（8） Verify that:

1） The tap changer would automatically return to original position if the AC voltage is unchanged.

2） Firing angle back within control limits.

3） DC voltage back to nominal value.

4） The tap position in Matiari is increased to maintain firing angle within control limits.

5） Maintained transmitted current.

（9） Record and save test data

5 Pole 2 Heat Run Test and Special Measurements

5.1 Test Objective

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

5.2 Preconditions

（1）all low power tests have been finished at normal power direction.

（2）AC system precondition:

1) The 500kV bus voltage of two AC systems is about 500~530kV.

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

[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:

[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

5.3 Test Content and Procedure

5.3.1 Pole 2 Run at 1.00 p.u. in Monopole without Redundant Cooling

Notes: The procedure would be accomplished in parallel with 4.3.1-4.3.2.

（1） Verify: Pole2 is in normal operation with power 2000MW.

（2） Verify: the Redundant Cooling is out of service.

（3） During the pole2 in operation for 4 hours at 1.0 p.u. The following verifications should be carried during this period. If any of the transformers has not reached steady state temperature, then continue for another 1/2 hour.

1) Verify that the reference is fulfilled after the ramping is completed.

2) Verify that the measured currents and voltages at DC and AC side are correct.

3) Read, record and plot valve cooling water temperature inlet and outlet (local and/or remote indications) continuously, until reasonable stable temperature is reached.

4) Read,record and plot temperature of coil winding and hot spot in converter transformer every 30 minutes (local and/or remote indications) until reasonable stable temperature is reached, and record smoothing reactor temperatures with IR camera every 30 min and at end of test.

5) Read and record AC-side individual harmonics, D_n, total harmonic distortion, THD, Telephone Harmonic Form Factor, THFF, in Matiari and LAHORE during pole2 power ramping.

6) Read or calculate and record DC-side harmonics and Ieq in Matiari and LAHORE C/S from the power quality analyser .

7) Perform special measurements as described in below section 5.3.3-5.3.6.

8) **The Power Loss in Station** should be measured by subtracting the DC power from the power flowing into the converter transformer.

（4） Record and save all data.

5.3.2 Pole 2 Run at 1.1 p.u. in Monopole with Redundant Cooling

（1） Verify: Pole2 is in normal operation with power 2200MW.

（2） During the pole 2 in operation for 2 hours at 1.1 p.u. The following verifications should be carried during this period.

1) Verify that the reference is fulfilled after the ramping is completed.

2) Verify that the measured currents and voltages at DC and AC side are correct.

3) Read, record and plot valve cooling water temperature inlet and outlet (local and/or remote indications) continuously, until reasonable stable temperature is reached (temperatures should be stable within approximately 15 minutes).

4) Read,record and plot temperature of coil winding and hot spot in converter transformer every 30 minutes (local and/or remote indications) until reasonable stable temperature is reached (temperatures should be stable within approximately 3 hours).

5) Read and record AC-side individual harmonics, Dn, total harmonic distortion, THD, Telephone Harmonic Form Factor, THFF, in Matiari and LAHORE during pole2 power ramping.

6) Read or calculate and record DC-side harmonics and Ieq in Matiari and LAHORE from the power quality analyser.

7) Perform special measurements as described in below section 5.3.3-5.3.6.

（3） Ramp the power down to 2000MW (3030A), at 50MW/min

（4） Record and save all data.

5.3.3 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.

5.3.4 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.

5.3.5 Station Auxiliary 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 status **Ready for Operation**, the loads on the 400V power level are measured within one scheduled time period (for example 5 times measurements in one hour) with recording sheets. The measurement results are averaged to get

values.

（2） Verify that these measured loss values are within limited value specified by technical specification.

（3） When the pole 2 is in operation at 1.0 p.u. or 1.1 p.u., the loads on the 400V power level are measured within one scheduled time period (for example 5 times measurements in one hour). The measurement results are averaged to get values, which are equivalent losses to the no-load or fixed Auxiliary Power losses.

（4） Record and save all data.

5.3.6 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.

5.3.7 Fault in Pole 1 Running at High Power with Pole 2 at minimum in Pole Power Control

（1） Verify: P1 running at high power (which value will be confirmed together with NPCC before testing) with Bipole power control, P2 running at 200MW with Pole Power Control.

（2） Verify: NPCC confirms that AC corridor can withstand the transfer power before testing.

（3） Matiari C/S push the ESOF button, P1 is blocked by ESOF.

（4） Verify: P2 does not pick up the power, the DC power of pole1 transfer to AC corridor.

（5） Record the overvoltage and tripping times of the filters at both converter stations.

（6） Record and save all data.

6 Pole1 High Power Test, Reversed Power Direction (Optional)

6.1 Test Objective

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

6.2 Preconditions

（1）all low power tests have been finished at reversed power direction

（2）AC system precondition:

1) The 500kV bus voltage of two AC systems is about 500~530kV.

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

6.3 Test Content and Procedure

6.3.1 Pole Start

（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） According the actual situation and test requirement, verify the DC configuration is GROUND RETURN(GR).

（4） Switch RPC to **Q control** in both stations.

（5） Start the pole1 at minimum power in **Reversed Power Direction**, GROUND RETURN(GR)**,** 200MW (303A), ramp rate 100MW/min.

（6） Record and save all data.

6.3.2 Power Ramp

（1） Ramp the power up to 1000MW at 50MW/min rate in steps of 200MW with an interval of 2 min. The interval is to make sure the system is stable.

（2） 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.

（3） Ramp the power down to 200MW at 50MW/min rate in steps of 200MW with an interval of 2 min. The interval is to make sure the system is stable.

（4） Verify:

3) the ramping process is smooth and continuous without transient changes in the power transmission.

4) the references are fulfilled after the ramping is completed.

（5） Stop the pole.

（6） Record and save test data.

7 Safety measures and special points for the station tests

7.1 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 except observers as in 3 above is allowed to 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 under NPCC direction.

（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.

7.2 For AC system

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

8 Annex

HVDC--High Voltage Direct Current

DC-- Direct Current

AC--Alternative 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

MRTB-- Metallic Return Transfer Breaker

GRTS-- Ground Return Transfer switch

NBGS-- Neutral Bus Ground Switch