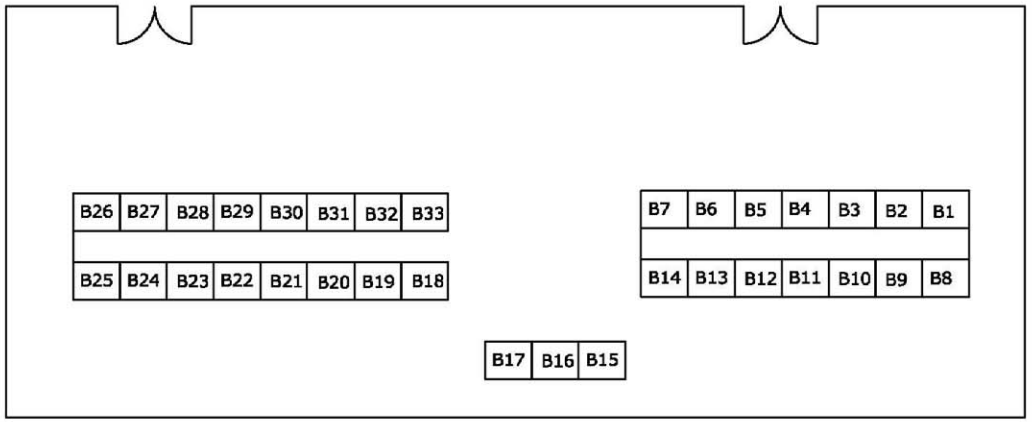
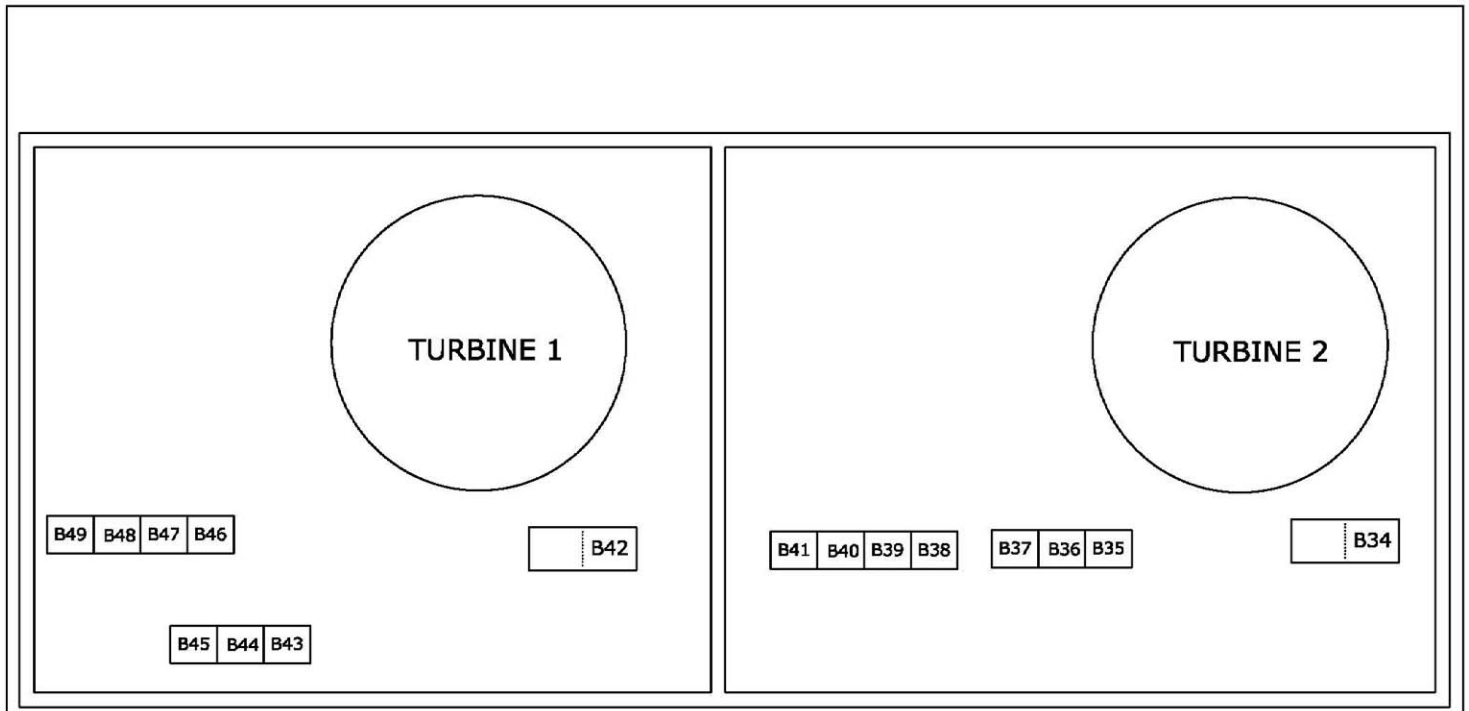
3. Canyon Power Station



LEGAND

B1 : DC AUX. SERVICE - UNIT 2
B2 : AC AUX. SERVICES- UNIT 2
B3 : TURBINE FAULTS - UNIT 2
B4 : GENERATOR TRF.- UNIT 2
B5 : TX. LINE - UNIT 2 BUSBAR
B6 : LAXAPANA TX. LINE & SYNCHRO
B7 : INTAKE VALVE & PENSTOCK GUARD VALVE - UNIT 2
B8 : DC RELAYS - UNIT 2
B9 : AC RELAYS - UNIT 2
B10 : GEN. TURB. CONTROL RELAYS- UNIT 2
B11 : GEN. TRF & TRANSMISSION PROTECTION RELAYS
B12 : GEN. RELAY & TRF. RELAY- UNIT 2
B13 : AUTO CONTROL RELAYS-UNIT 2
B14 : RECORDER (TEMP/ KWhr/VAR) - UNIT 2
B15 : COMMUNICATION
B16 : COMMUNICATION
B17 : COMMUNICATION
B18 : TX. LINE RELAYS
B19 : AUTO CONTROL - UNIT 1
B20 : GEN. TRF & TRANSMISSION PROTECTION RELAYS
B21 : GEN. RELAY & TRF. RELAY- UNIT 1
B22 : GEN. TURB. CONTROL RELAYS- UNIT 1
B23 : AC RELAYS - UNIT 1
B24 : DC RELAYS - UNIT 1
B25 : RECORDER (TEMP/ KWhr/VAR) - UNIT 1
B26 : INTAKE VALVE & PENSTOCK GUARD VALVE - UNIT 1
B27 : AUTO SYNCHRONIZATION
B28 : LAXAPANA TX. LINE
B29 : GENERATOR TRF.- UNIT 1
B30 : TURBINE FAULTS - UNIT 1
B31 : AC AUX. SERVICES- UNIT 1
B32 : DIESEL GENERATOR
B33 : DC AUX. SERVICE - UNIT 1

CEYLON ELECTRICITY BOARD CANIYON POWER STATION			
FIG.3.5-1/3 MAIN CONTROL ROOM LAYOUT			
DATE : 19/08/2004	SCALE : NTS	DRAWN : THUSITHA	CHKD : OKADA



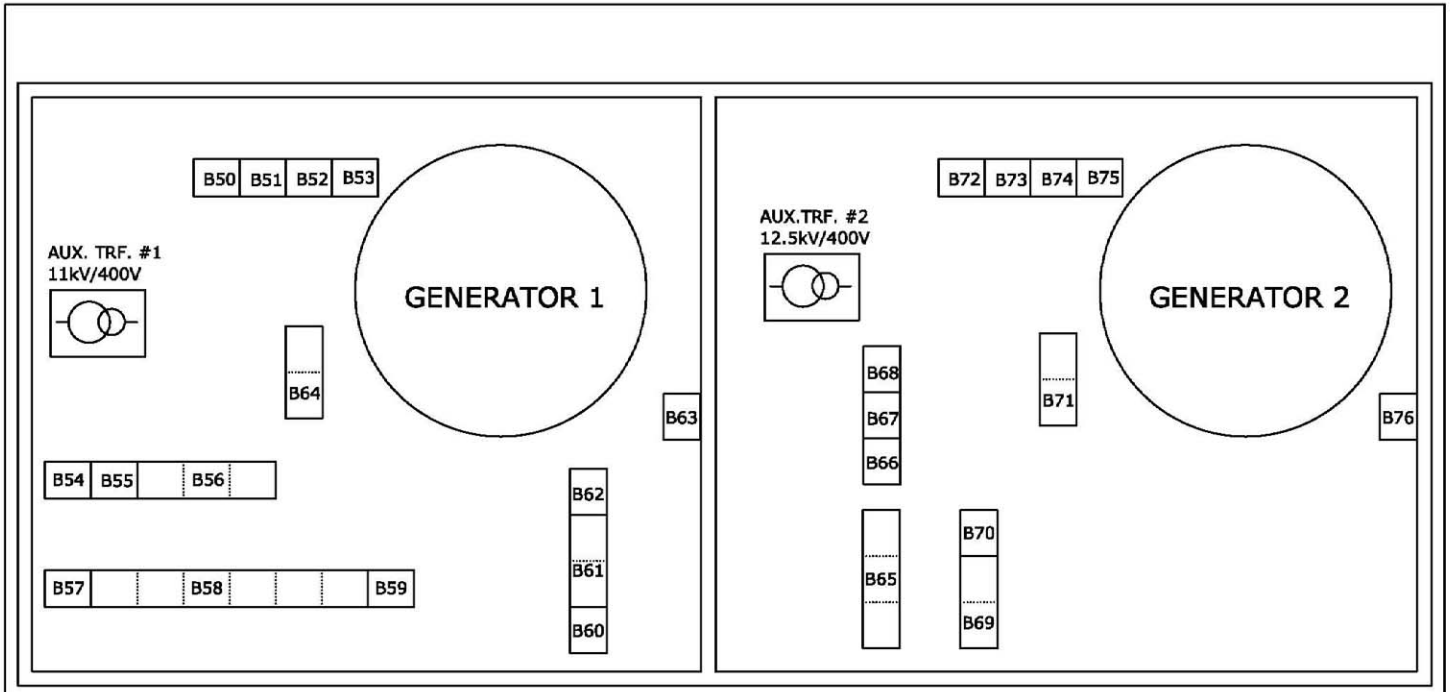
LEGAND

B34 : TURBINE & GOVERNOR CONTROL -# 2
B35 : AVR- # 2
B36 : EXCITATION -# 2
B37 : EXCITATION-# 2
B38 : AC INCOMING & AUXIILIERIES-# 2
B39 : UNIT CONTROL- # 2
B40 : UNIT AC DISTRIBUTION- # 2
B41 : EMERGENCY GOVERNOR OIL PUMP - # 2

B42 : TURBINE & GOVERNOR CONTROL -# 1
B43 : AVR- # 1
B44 : EXCITATION -# 1
B45 : EXCITATION-# 1
B46 : AC INCOMING & AUXIILIERIES-# 1
B47 : UNIT CONTROL- # 1
B48 : UNIT AC DISTRIBUTION- # 1
B49 : EMERGENCY GOVERNOR OIL PUMP - # 1

CEYLON ELECTRICITY BOARD
CANIYON POWER STATION
FIG.3.5-2/3 TURBINE FLOOR LAYOUT

DATE : 19/08/2004	SCALE : NTS	DRAWN : THUSITHA	CHKD : OKADA

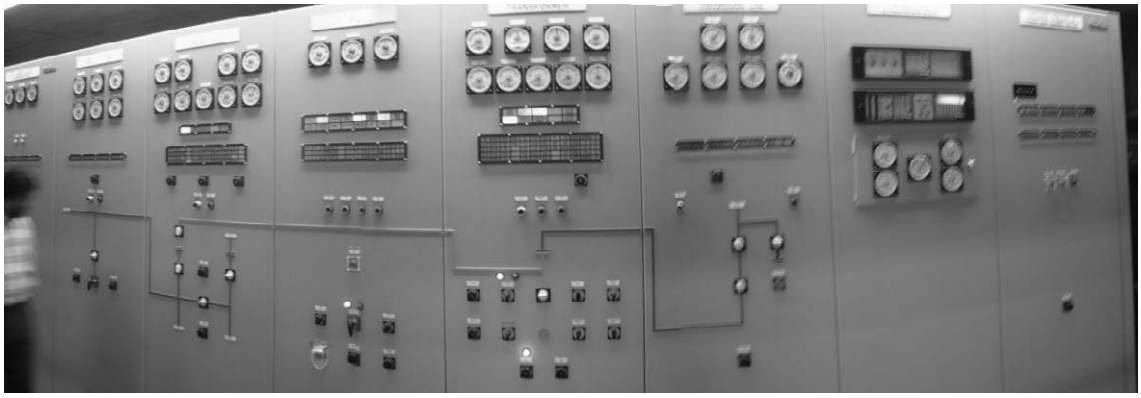


LEGAND

B50 : LOAD BREAK SWITCH -# 1
B51 : CIRCUIT BREAKER- # 1
B52 : INSTRUMENT TRF. -# 1
B53 : SURGE ARRESTER & EXC. TRF. -# 1
B54 : BATTERY CHARGER-# 1
B55 : BATTERY CHARGER- # 2
B56 : DC DISTRIBUTION- # 1
B57 : ESSENTIAL INCOMING
B58 : AUXILIERY SERVICES -# 1
B59 : NON ESSENTIAL INCOMING - # 1
B60 : ESSENTIAL LIGHTING - # 1
B61 : NON ESSENTIAL LIGHTING - # 1
B62 : DC LIGHTING -# 1
B63 : AC & VENTILATION - # 1
B64 : GEN. NEUTRAL GROUNDING - # 1
B65 : ESSENTIAL INCOMING
B66 : BATTERY CHARGER-# 3
B67 : BATTERY CHARGER- # 4
B68 : DISTRIBUTION
B69 : NON ESSENTIAL LIGHTING - # 2
B70 : DC LIGHTING -# 2
B71 : GEN. NEUTRAL GROUNDING - # 2
B72 : LOAD BREAK SWITCH -# 2
B73 : CIRCUIT BREAKER- # 2
B74 : INSTRUMENT TRF. -# 2
B75 : SURGE ARRESTER & EXC. TRF. -# 2
B76 : AC & VENTILATION - # 2

CEYLON ELECTRICITY BOARD CANIYON POWER STATION			
FIG.3.5-3/3 GENERATOR FLOOR LAYOUT			
DATE : 19/08/2004	SCALE : NTS	DRAWN : THUSITHA	CHKD : OKADA

Picture-3.6 Control / Protection Equipment Board



Unit 1 main & station service control board

Unit 2 main & station service control board and operator desk

Protection relay boards

Inside of both control & protection boards

Turbine control & actuator cubicles

Excitation cubicle

DC distribution board

Battery charger cubicle

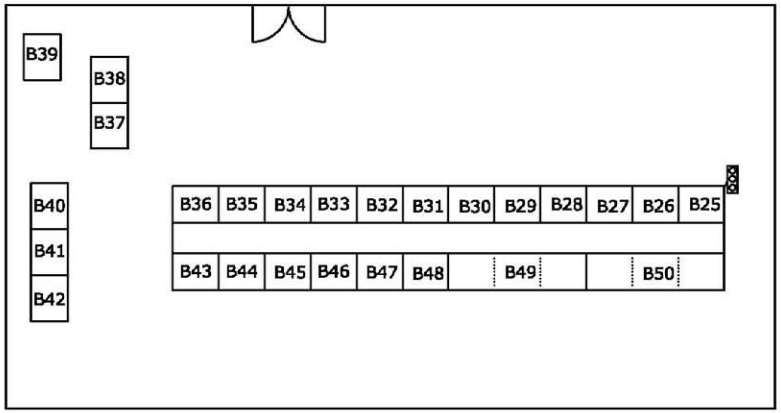
Battery of control system

Motor control center (MCC)

Telecommunication system

Indicator of GOV SD (5%)

4. New Laxapana Power Station



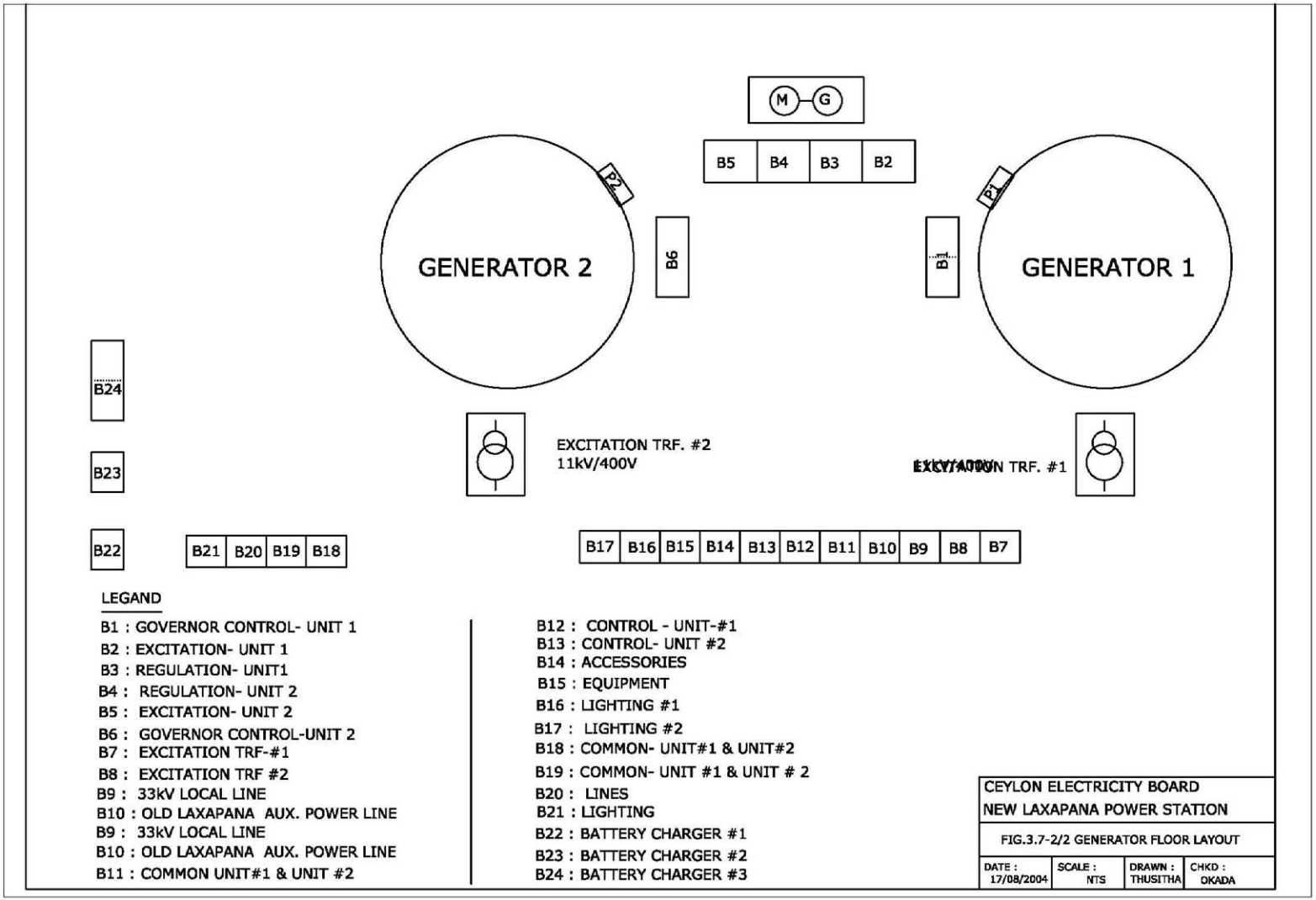
LEGAND

B25 : GEN-TRF # 1 OPERATION
B26 : GEN-TRF #1 INDICATION
B27 : GEN-TRF # 1 INDICATION
B28 : GEN-TRF # 2 OPERATION
B29 : GEN-TRF #2 INDICATION
B30 : GEN-TRF # 2 INDICATION
B31 : STATION TOTALIZING
B32 : BALANGODA 132kV LINE #2
B33 : BALANGODA 132kV LINE #1

B34 : POLPITIYA 132kV LINE #1
B35 : POLPITIYA 132kV LINE #2
B36 : CANIYON 132kV LINE
B37 : SUPERVISORY PANEL #1
B38 : SUPERVISORY PANEL #2
B39 : COMMUNICATION
B40 : BUS BAR PROTECTION
B41 : BUS BAR PROTECTION
B42 : BUS BAR PROTECTION

B43 : PROT.RELAYS - CANIYON LINE
B44 : PROT. RELAYS POLPITIYA LINE 2
B45 : PROT.RELAYS POLPITIYA LINE 1
B46 : PROT.RELAYS BALANGODA LINE1
B47 : PROT.RELAYS BALANGODA LINE2
B48 : RELAYS- TOTALIZING PANEL
B49 : PROT.RELAYS GEN.TRF #2
B50 : PROT.RELAYS GEN.TRF #1

CEYLON ELECTRICITY BOARD NEW LAXAPANA POWER STATION			
FIG.3.7-1/2 MAIN CONTROL ROOM LAYOUT			
DATE : 17/08/2004	SCALE : NTS	DRAWN : THUSITHA	CHKD : OKADA


M
G
B5
B4
B3
B2
P2
P1
GENERATOR 2
B6
B1
GENERATOR 1
B24
B23
B22
B21
B20
B19
B18
EXCITATION TRF. #2
11kV/400V
EXCITATION TRF. #1
B17
B16
B15
B14
B13
B12
B11
B10
B9
B8
B7
LEGAND
B1 : GOVERNOR CONTROL- UNIT 1
B2 : EXCITATION- UNIT 1
B3 : REGULATION- UNIT1
B4 : REGULATION- UNIT 2
B5 : EXCITATION- UNIT 2
B6 : GOVERNOR CONTROL-UNIT 2
B7 : EXCITATION TRF-#1
B8 : EXCITATION TRF #2
B9 : 33kV LOCAL LINE
B10 : OLD LAXAPANA AUX. POWER LINE
B9 : 33kV LOCAL LINE
B10 : OLD LAXAPANA AUX. POWER LINE
B11 : COMMON UNIT#1 & UNIT #2
B12 : CONTROL - UNIT-#1
B13 : CONTROL- UNIT #2
B14 : ACCESSORIES
B15 : EQUIPMENT
B16 : LIGHTING #1
B17 : LIGHTING #2
B18 : COMMON- UNIT#1 & UNIT#2
B19 : COMMON- UNIT #1 & UNIT # 2
B20 : LINES
B21 : LIGHTING
B22 : BATTERY CHARGER #1
B23 : BATTERY CHARGER #2
B24 : BATTERY CHARGER #3
CEYLON ELECTRICITY BOARD
NEW LAXAPANA POWER STATION
FIG.3.7-2/2 GENERATOR FLOOR LAYOUT
DATE : 17/08/2004
SCALE : NTS
DRAWN : THUSITHA
CHKD : OKADA

Picture 3.8 Control / Protection Equipment Board

Control boards of turbine- generator and transmission line

Control boards of transmission line

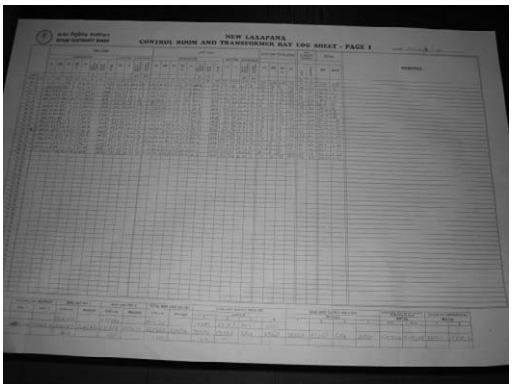
Protection relay boards

Protection relay boards and renewed lockout relay # 86

Auxiliary control board (NFB and ACB)

Governor & Actuators cubicle

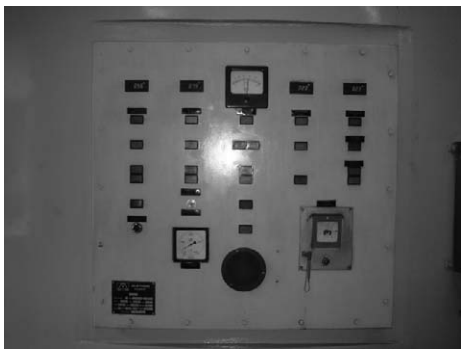
Excitation regulator board



Operating record sheet

Supervisory CRT
(for Old Laxapana ps of remote station)

Compressor control panel



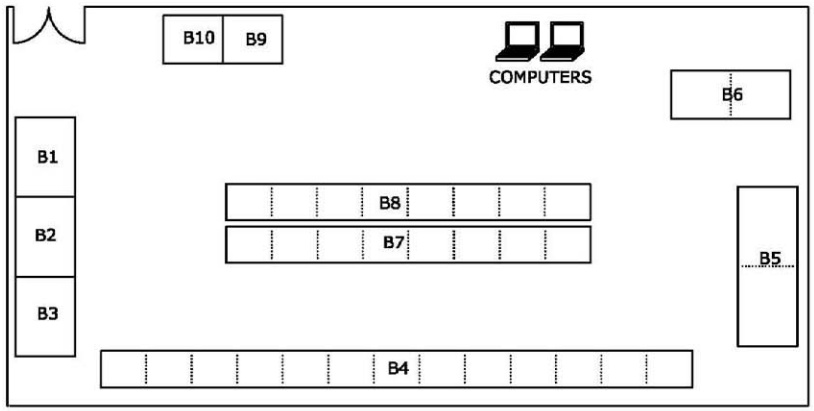
Auxiliary panel of Generator

Battery charger of control & communication

Battery of communication system

Battery of control system

5. Polpitiya Power Station

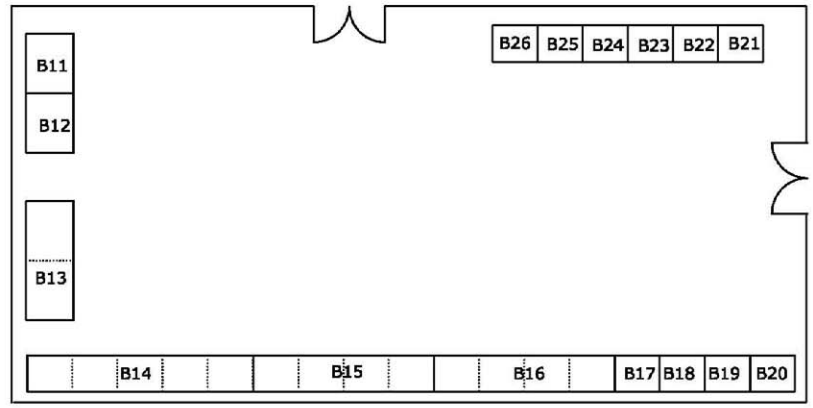


LEGAND

B1 : DC MAIN DB COMMON SUPPLY
B2 : DC MAIN DB SUPPLY 2
B3 : DC MAIN DB SUPPLY 1
B4 : TRANSMISSION LINE CONTROL & PROTECTION
B5 : STATION CONTROL BOARD

B6 : DATA LOGGER PANELS
B7 : GENERATOR CONTROL & PROTECTION
B8 : SWITCHGEAR CONTROL & PROTECTION
B9 : 220 V DC RECTIFIER #1
B10 : 220V DC RECTIFIER #2

CEYLON ELECTRICITY BOARD SAMANALA (Polpitiya) POWER STATION			
FIG.3.9-1/2 MAIN CONTROL ROOM LAYOUT			
DATE : 17/08/2004	SCALE : NTS	DRAWN : THUSITHA	CHKD : OKADA



LEGAND

B11 : GOVERNOR CONTROL - UNIT#2
B12 : GOVERNOR CONTROL - UNIT #1
B13 : STATION SUPPLY #1
B14 : STATION SUPPLY #2
B15 : UNIT SUPPLY #2
B16 : UNIT SUPPLY #1
B17 : COOLING WATER PUMPS
B18 : AUX. TRANSFORMER INCOMER-UNIT#2
B19 : AUX. TRANSFORMER INCOMER-UNIT#1
B20 : DIESEL GENERATOR INCOMER
B21 : FIELD BREAKER-UNIT #1
B22 : CONVERTER -UNIT #1
B23 : REGULATOR-UNIT#1
B24 : FIELD BREAKER-UNIT #2
B25 : CONVERTER -UNIT #2
B26 : REGULATOR -UNIT#2

CEYLON ELECTRICITY BOARD
SAMANALA (Polpitiya) POWER STATION
FIG.3.9-2/2 MOTOR CONTROL ROOM LAYOUT

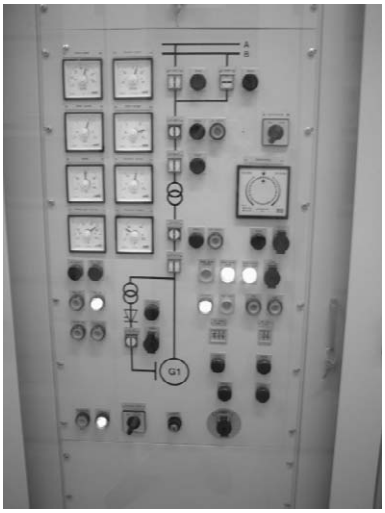
DATE :	SCALE :	DRAWN :	CHKD :
17/08/2004	NTS	THUSITHA	OKADA

Picture 3.10 Control / Protection Equipment Board

Control Boards of Generator / Transformer (left site) and Transmission Line (right side)

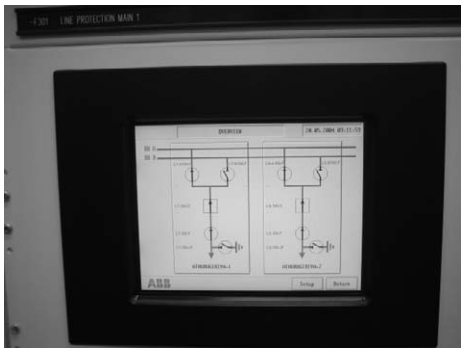
Control Desk with CRT (below)

Control Board of Transmission/Line



Control Board of Gen & Tr.

Station Service Boards



Show Display on Control Board

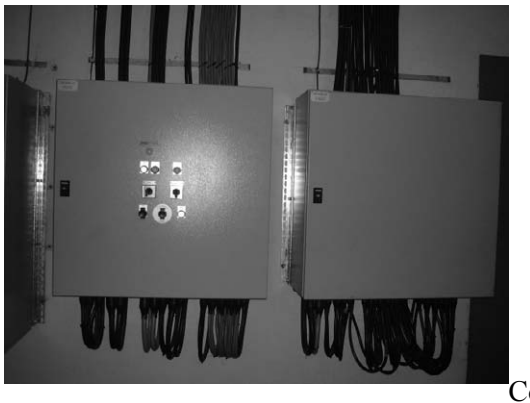
Excitation Boards

Governor Control Board

Battery Charger of Control

DC Distribution Boards

Station Service Cub. & Unit 1 & 2 Motor Control Center (MCC)



Control Panel of Turbine (left) and Generator Auxiliary Equipment (right)

Battery Charger Cubicles of Communication

Communication Boards

Battery of Control and Communication Equipment

Cabling Layout

6. Summary

Table 3.11 Control / Protection Equipment Summary for Investigation

Item	*Wimalasurendra P.S*	*Canyon P.S*	*Old Laxapana P.S*	*New Laxapana P.S*	*Polpitiya P.S*
Commissioning year of hydropower station	Jan.'64	Mar.'83 and '88	Dec.'50 and Dec.'58	Feb.'74 and Mar.'74	Apr.'69
Replaced Replacement year of control and protection equipment	-	-	Stage I : 1995 Stage II : 2003	-	2003
1. Control equipment	Manual control system (Governor, Exciter, Parallel in, etc.) AVR is out of order	One man control system	One control system	One man control system (Remote control from Old Laxapana P.S)	One man control system
Measures	Need replacement	OK	OK	Need r Replacement needed	OK
2. Protection equipment	Electro magnetic relays	Electro magnetic relays	Numerical relay	Old system with electromagnetic relays	Numerical relay
Measures	Need replacement.	OK	OK	Need Replacement needed	OK
3. Control power source equipment	220V battery control and uninterruptible power source	220V battery control	220V battery control	220V battery control and uninterruptible power source	220V battery control
Measures	Need replacement and installation	OK	OK	Need Replacement and installation needed	OK
4. Communication equipment	PLC limited capacity	PLC limited capacity	Communication equipment –	Communication Equipment at Old Laxapana	
Measures	Telephone system: OK Communication line OPGW : needs installation for SCADA system	Telephone system: OK Communication line OPGW : needs installation for SCADA system	Telephone system: OK Communication line OPGW : needs installation for SCADA system	Telephone system: OK Communication line OPGW : needs installation for SCADA system	Telephone system: OK Communication line OPGW : needs installation for SCADA system
5. Dam distribution equipment	Dam control at Castlereigh	Poor operation	Power taken from the grid	Power taken from the grid	Dam distribution feeder cable from Old Laxapana
Measures	Need future replacement needed	Need future replacement needed	Need future replacement needed	Need future replacement needed	Need future replacement needed

APPENDIX C-4

CEB における Canyon 発電所点検項目

1. INSPECTION ITEMS FOR ELECTRICAL EQUIPMENT IN CANYON HYDROPOWER STATION

1.1 Electrical Equipment

Equipment	No.	Inspection Items	Interval
Moussakelle Dam	1	Replace fused bulbs	1 Week
	2	Inspection of the electrical wiring and accessories of the radial gates.	1 Week
	3	Inspection of the electrical wiring and accessories of the Intake gates.	1 Week
	4	Inspection of the electrical wiring and accessories of the Needle Valve.	1 Week
	5	Operational tests of the diesel generator with lighting load, record diesel generator data.	1 Week
	6	Cleaning of all accessories and cubicles	1 Month
	7	Insulation resistance	3 Months
	8	Operational check of radial gates using a standby diesel generator	3 Months
T.I.V.H.	1	Replace fused bulbs	1 Month
	2	Clean the meters' cubicle and the accessories	1 Month
	3	General inspection of limit switches wiring etc.	2 Weeks
M/K Diesel Engine and Generator 28 kVA	1	Operation test of the diesel generator with the lighting load. Record diesel generator data	1 Week
	2	Cleaning of all accessories and cubicles	1 Month
	3	Measure and record generator insulation resistance	3 Months
	4	Check transfer switch	6 Months
Battery Bank P.G.V.H.	1	Measure and record total Voltage on battery	2 Weeks
	2	Check acid level	2 Weeks
	3	Check for dust and clean the battery cubicle	2 Weeks
	4	Check and record individual cell Voltage	1 Month
	5	Check for discharge at terminals	1 Month
	6	Measure and record specific gravity of all cells	1 Month
	7	Check for abnormalities	1 Month
	8	Tighten connections	6 Months
	9	Equalizing charges	3 Months
Neutral Grounding Transformer	1	Check winding core and leads	1 Month
	2	Check and clean wedge supports	1 Month
	3	Clean external surfaces	1 Month
	4	Check for corrosion in damped device	1 Year
	5	Check for loose bolts	1 Year
	6	Check insulation resistance	1 Year
Battery Charger P.G.V.H.	1	Measure A.C. input voltage	1 Month
	2	Check the lamps	1 Month
	3	Check floating and equalizing voltages	1 Month
	4	Check for abnormalities	3 Months
	5	Clean and tighten the contacts	6 Months
	6	Check the manual operation	3 Months
	7	Calibrate CTs and the meters	3 Months

Equipment	No.	Inspection Items	Interval
33 kV Stand by Auxiliary Transformer	1	Check temperature and oil level	Every day
	2	Check for abnormalities	1 Month
	3	Check for oil leakage	1 Month
	4	Check breather oil level	1 Month
	5	Change silica gel	when colors change
	6	Bolt tightening and cleaning	6 Months
	7	Check thermometers	1 Year
	8	Inspect and clean the bushing	1 Year
	9	Inspect and clean the tap changer	1 Year
132 kV Main Transformer	1	Check temperature and oil level	Everyday
	2	Check for abnormalities	1 Month
	3	Check for oil leakage	1 Month
	4	Check breather oil level	1 Month
	5	Change cover silica gel	When color change
	6	Check radiators for oil leakage	1 Month
	7	Check bushing for oil leakage	1 Month
	8	Check fan bearings for oil leakage	1 Month
	9	Bolt tightening and cleaning	6 Months
	10	Measure insulation resistance of winding	1 Year
	11	Measure dielectric strength of oil	1 Year
	12	Measure acid volume of oil	1 Year
	13	Operate tap changer through its full range	1 Year
	14	Check for oil leakage of the tap changer and lubricate gears	1 Year
	15	Check radiators	1 Year
	16	Check bushings for local heating damage or pollution of porcelain and oil leads	1 Year
	17	Check and clean pressure relief device	1 Year
	18	Check and clean indicators	1 Year
	19	Clean and retighten terminal box of relays	1 Year
	20	Check for operation of alarm switches	1 Year
	21	Measure insulation resistance, inspect the wiring of protection and control circuit	1 Year
	22	Measurement of "Tan Δ" of the transformer	3 Years
	23	Measure insulation resistance of bushing and arrester	2 Years
	24	Filter insulation oil if abnormality found on test 11,12,22	Abnormality found
	25	Check and clean inside contents	5 Years
132 kV Line Transformer	1	Clean the contacts and accessories	1 Year
	2	Inspect the contacts	1 Year
	3	Lubricate levers	2 Years
	4	Lubricate the operating device	2 Years
132 kV O.C.B.	1	Inspect the O.C.B. for any abnormalities	1 Month
	2	Clean O.C.B. and all insulators	1 Month
	3	Check the oil level and pressure in the breaking unit	1 Month
	4	Lubrication of bearings	1 Year
	5	Do the sample test check of oil	3 Years
	6	Remove inspection covers and clean, anti-rust treatment, lubricate and check oil in the dashpot	6 Years
	7	Complete overhaul	12 Years

Equipment	No.	Inspection Items	Interval
12.5 kV Auxiliary Transformer	1	Check temperature and oil level	Everyday
	2	Check for abnormalities	1 Month
	3	Check for oil leakage	1 Month
	4	Check breather oil level	1 Month
	5	Change silica gel when color changes to pink	Acc. to requirement
	6	Bolt tightening and cleaning	6 Months
	7	Check thermometers	1 Year
	8	Inspect and the tap changer	1 Year
	9	Inspect and clean the bushings	1 Year
	10	Check pressure relief device	1 Year
	12	Measure wedge and bushing insulation resistance	1 Year
	13	Measure dielectric strength of insulation oil	1 Year
	14	Measure " Tan Δ " of the transformer	1 Year
	15	Check for operation of alarm switches	3 Years
	16	Measure insulation resistance and inspect the wiring of protection and control circuits	1 Year
	17	Filter insulation oil if abnormality found on tests 12,13,and 14	1 Year
132 kV Line Earthing Switch	1	Inspect the contacts and accessories	1 Year
	2	Clean the contacts and accessories	1 Year
	3	Lubricate levers	2 Years
	4	Lubricate the operating device,	2 Years
Main T/F Fire Protection System	1	Testing of main T/F fire protection using emergency fire protection button at the switch yard	1 Year
	2	Testing of main T/F fire protection using fire detector	1 Year
	3	Testing of main T/F fire protection using emergency fire protection button at the cubicle on the power house	1 Year
Excitation Transformer	1	Inspect the winding, core, connection lead for any damage discoloration and dust deposit	1 Month
	2	Check the wedge supporting structure for any damage	1 Month
	3	Check for contamination in the air filter	1 Month
	4	Clean the winding support, core and winding	1 Month
	5	Check for corrosion	3 Months
	6	Measure the insulation resistance	6 Months
	7	Check the conductive parts for any loosing over heating and corrosion	6 Months
	8	Check the cooling fans	6 Months
	9	Check for loosing in any of the parts	6 Months
Generator	1	Check the operation condition from log sheets	Everyday
	2	Check for the rated amount of cooling water flow in the air cooler	1 Week
	3	Check for unusual smell of the winding	Everyday
	4	Check insulators for discoloration	1 Year
	5	Check for wedges	1 Year
	6	Check for loose or broken binding strands	1 Year
	7	Check the lead wires	1 Year
	8	Check the station winding temperature for abnormalities	1 Week
	9	Check for anything unusual	1 Week
	10	Check for water leakage from cooling water pipes	1 Month
	11	Check for oil leakage	1 Month

Equipment	No.	Inspection Items	Interval
	12	Check all the joints for any sign of discoloration and overheating	1 Month
	13	Check the field winding temperature for abnormalities	1 Week
	14	Check tightness of all the bolts and flexibility of the leads	2 Weeks
	15	Inspect the bus bar	1 Year
	16	Clean inside the generator housing	1 Month
	17	Generator air cooler cleaning	1 Month
Instrument Transformer	1	Check for loose contacts	1 Month
	2	Check for any abnormalities	1 Month
	3	Clean inside the cubicles	1 Month
	4	Check for deformation of insulation	1 Year
Brushless Exciter	1	Measure A.C. exciter pole coil insulation resistance	1 Year
	2	Measure exiting current pickup coil insulation resistance	1 Year
	3	Measure rotor insulation resistance	1 Year
	4	Inspect the rotary rectifier for abnormalities of connection parts	1 Year
	5	Inspect the fuse indicator of silicon rectifier	1 Year
	6	Measure reverse resistance of silicon rectifier	1 Year
12.5 kV O.C.B.	1	Cleaning inside the cubicle	1 Month
	2	Check oil level	1 Year
	3	Check the dielectric strength	2 Years
	4	Check Insulation oil	5 Years
	5	Check weaker contacts (5000 operations)	5 Years
	6	Check parts of arc quenching chamber (5000 operations)	5 Years
	7	Lubrication (5000 operations)	5 Years
	8	Clean gas purge hole (5000 operations)	5 Years
	9	Replace gas purge plug (5000 operations)	5 Years
	10	Clean completely (5000 operations)	5 Years
Load Break Switch	1	Clean inside the cubicle	1 Month
	2	Check for loose contacts and abnormalities	1 Month
	3	Cleaning and greasing completely	1 Year
	4	Check for any burnt parts	1 Month
	5	Check the arc chamber	5 Years
	6	Check the arching ring	5 Years
	7	Check the quenching device	5 Years
	8	Check auxiliary main contacts and damping plate	5 Years
	9	Check fixed contact support insulation	5 Years
	10	Check that the auxiliary moving contact runs into auxiliary mating contact	5 Years
Governors	1	Check the system motor	1 Year
	2	Check the minimum operating voltage of solenoid valve	3-5 years
	3	Check the limit switches for operation	1 Year
	4	Cleaning the cubicle and instrument	1 Month
	5	Check oil pump motor AC and DC	1 Month
	6	Check insulation resistance of the oil pump motors	6 Months
14.5 kV current Transformer	1	Check for oil leakage	1 Week
	2	Check for paint coating damage	1 Month
	3	Check for insulators	1 Month
	4	Clean the insulators and supporting parts	3 Months
	5	Measure the insulation resistance	1 Year

Equipment	No.	Inspection Items	Interval
Battery Changer No. 01	1	Measure A.C. input voltage	1 Month
	2	Clean the cubicle	1 Month
	3	Tighten the contacts	3 Months
	4	Check temperature rise in thyristor	3 Months
	5	Check contacts of variable resistor in gate control	6 Months
	6	Check temperature in transformer coil	6 Months
	7	Check for control switches	6 Months
	8	Check relays and magnetic switches	6 Months
	9	Check meters for correct indicators	1 Year
	10	Check terminal of terminal boards	1 Year
Battery Charger No. 02	1	Measure A.C. input voltage	1 Month
	2	Clean the cubicle	1 Month
	3	Tighten the contacts	3 Months
	4	Check temperature rise in thyristor	3 Months
	5	Check contacts of variable resistor in gate control	6 Months
	6	Check temperature in transformer coil	6 Months
	7	Check for control switches	6 Months
	8	Check relays and magnetic switches	6 Months
	9	Check meters for correct indicators	1 Year
Main Battery Bank	1	Measure and record total voltage on floating	1 Week
	2	Check acid valve	1 Week
	3	Check for dirt and clean	1 Week
	4	Clean battery charger room	1 Week
	5	Check and record individual cell voltage	1 Week
	6	Check for discharger of terminal	1 Week
	7	Measure and record specific gravity of all cells	1 Week
	8	Check for abnormalities	1 Week
	9	Confirm there is no obstruction of ventilation apparatus	1 Month
	10	Tightening connections	6 Months
	11	Equalizing charge	3 Months
A.C. and D.C. Distribution Board	1	Clean all cubicles	1 Month
	2	Check auto breakers	1 Month
	3	Check magnetic conductor	1 Month
	4	Check auxiliary relays	1 Month
	5	Check D.C. electromagnetic conductor	1 Month
	6	Check thermal overload relays	1 Month
Relays and Control Boards	1	Clean main control board relays, meters at out side control room	1 Week
	2	Clean the governor cubicle, meters and switches	1 Week
	3	Clean AVR cubicle and excitation	1 Week
	4	Check the contacts of relays	1 Week
	5	Test the relays	1 Week
Wide Scale Self Balancing Recorder	1	Replace the recording chart at appropriate time	Appropriate time
	2	Replace the recording pen when the color becomes too light	When color changes
	3	Replace the printing pad, when the color of print becomes too light	When color changes
	4	Lubricate the necessary parts	1 Year
	5	Retighten external terminal and interior mechanism	1 Year
	6	Effect calibration if required	1 Year
	7	Replace the component parts according to manufacturer recommendations	1 Year

Equipment	No.	Inspection Items	Interval
Cooling Water Pump 1 and 11	1	Check the motors for sound operation	1 Week
	2	Check the motor insulation	1 Week
48 V Battery Charger	1	Measure A.C. input voltage	1 Month
	2	Clean the cubicle	1 Month
	3	Tighten the contacts	3 Months
	4	Check temperature rise in rectifier elements	3 Months
	5	Check meters for correct indications	1 Year
48 V Battery Bank	1	Measure and record total voltage on floating	1 Week
	2	Check acid value	1 Week
	3	Check for dirt and clean as needed	1 Week
	4	Check and record individual cell voltage	1 Week
	5	Check for discharge at terminals	1 Week
	6	Measure and record specific gravity of all cells	1 Week
	7	Check for abnormalities	1 Week
	8	Tighten connections	6 Months
	9	Equalizing charge	1 Month
Canyon Dam	1	Replace fused bulbs	1 Week
	2	Inspection of the electrical wiring and accessories of the radial gates	1 Week
	3	Inspection of the electrical wiring and accessories of the Intake gates	1 Week
	4	Inspection of the electrical wiring and accessories of the vent	1 Week
	5	Operation test of the diesel generator with the lighting load	1 Week
	6	Clean all the accessories and cubicles	1 Month
	7	Insulation resistance measurement	3 Months
	8	Operational check of the radial gates using standby diesel generator	3 Months

1.2 Mechanical Equipment

Equipment	No.	Inspection Items	Interval
Moussakelle Dam	1	Greasing of all points	1 Week
	2	Clean the accessories and dam site	1 Week
	3	Inspection of gear wheels and lubrication	1 Month
	4	Operational check of the radial gates	1 Month
	5	Operational check of the needle valve	1 Month
	6	Inspection of the wire ropes	1 Month
	7	Routine maintenance of diesel engine	1 Month
	8	Compound the wire ropes	3 Months
	9	Gallery inspection	3 Months
Tunnel Inlet Valve House	1	Service the monorail hoist	1 Month
	2	Clean the accessories	1 Month
	3	Clean the floor, roof, walls, windows, doors and drains	1 Month
	4	Weed and clean the site	1 Month
Tunnel Inlet Valve	1	Check for water leakage at dismantling joints	2 Weeks
	2	Check for water leakage from clamped joints	2 Weeks
	3	Check for oil leakage from servomotor	2 Weeks
	4	Check for rust and damage if red parts are uncovered	2 Weeks
	5	Look for foreign matter on floor	2 Weeks
	6	Observation of vibration and noise	2 Weeks
	7	Check for peeling of paint	2 Weeks
	8	Check for water leakage from valve seat	1 Year
	9	Check for damage of valve body, seat casting, shaft etc.	1 Year
	10	Observe and record cavitation and pitting	1 Year
	11	Check for tightening[??] of rod and pin of servomotor	1 Year
	12	Check for discoloration and corrosion of shaft	3 Years
	13	Check for wear and damage to bearing bushes	3 Years
	14	Confirm the bush interior lubrication is satisfactory	3 Years
	15	Check for wear and damage of cylinder piston and packing	3 Years
By Pass Valve for Tunnel Inlet Valve	1	Check for vibration and noise	2 Weeks
	2	Check for water leakage from valve seat	1 Year
	3	Check and record cavitation and pitting	1 Year
	4	Check for damage to valve seat, casing, shaft etc.	1 Year
	5	Check for discoloration and corrosion of shaft	3 Years
	6	Check for wear damage and lubrication in bearing bushes	3 Years
	7	Check servomotor for oil leakage, tight pin	1 Year
	8	Check cylinder, piston and packing for wear damage	3 Years
Pressure Oil Supply System For Tunnel Inlet Valve	1	Check temperature of pumps and motors	2 Weeks
	2	Check for abnormal noise or vibration	2 Weeks
	3	Confirm that the sump oil level is normal	2 Weeks
	4	Check operation of oil pumps and driving motors	1 Month
	5	Check for oil leakage	1 Month
	6	Confirm oil level switches operates correctly	6 Months
	7	Check the oil and filter if necessary	1 Year
	8	Check discharged oil volume of pumps	1 Year
	9	Clean strainers	1 Year
Penstock Guard Valve	1	Check for water leakage at dismantling joints	2 Weeks
	2	Check for water leakagefrom clamped joints	2 Weeks
	3	Check for oil leakage from servomotor	2 Weeks

Equipment	No.	Inspection Items	Interval
	4	Check for rust and damagein uncovered parts	2 Weeks
	5	Inspect for foreign matteron floor	2 Weeks
	6	Observation of vibration and noise	2 Weeks
	7	Check for peeling paints	2 Weeks
	8	Check for water leakage from valve seat	1 Year
	9	Check for damage and valve body, seat casing, shaft etc.	1 Year
	10	Observe and record cavitation and pitting	1 Year
	11	Check tightness of rod and pin of servomotor	1 Year
	12	Inspect for shaft discoloration and corrosion	3 Years
	13	Check bearing bushes for wear and damage	3 Years
	14	Confirm the bush interior lubrication	3 Years
	15	Check cylinder piston and packing for wear and damage	3 Years
Penstock Guard Valve House	1	Service the monorail hoist	1 Month
	2	Clean the accessories	1 Month
	3	Clean the floor, roof, walls, windows, doors and drains	1 Month
	4	Weed and clean the site	1 Month
Bypass Valve For Penstock Guard Valve	1	Check for vibration and noise	2 Weeks
	2	Check for water leakage from valve seat	1 Year
	3	Check and record cavitation and pitting	1 Year
	4	Check for damage to valve seat, casing, shaft etc.	1 Year
	5	Check shaft for discoloration	3 Years
	6	Check for wear damage and lubrication in bearing bushes	3 Years
	7	Check servomotor for oil leakage, tightness of rod and pin	1 Year
	8	Check cylinder, piston and packing for wear damage	3 Years
Penstock	1	Cleaning of the sliding parts of the penstock	2 Weeks
	2	Tightening the sliding parts	2 Weeks
	3	Check the penstock for corrosion	2 Weeks
	4	Check for the leakage at the manhole	2 Weeks
	5	Check for leakage at the expansion joints	2 Weeks
	6	Tighteng them if necessary	2 Weeks
	7	Replace the braid packing if necessary	10 Weeks
	8	Paint the penstock line	10 Weeks
Pressure Oil Supply System For P.G.V.	1	Check temperature of pumps and motors	2 Weeks
	2	Check for abnormal noise or vibration	2 Weeks
	3	Confirm the sump oil level	2 Weeks
	4	Check operation of oil pumps and driving motors	1 Month
	5	Check for oil leakage	1 Month
	6	Confirm oil level switches operatecorrectly	6 Months
	7	Check the oil and filter if necessary	1 Year
	8	Check discharge oil volume pumps	1 Year
	9	Clean strainers	1 Year
Turbine Inlet Valve	1	Check for water leakage at dismantling joints	2 Weeks
	2	Check for water leakage from clamped joints	2 Weeks
	3	Check for oil leakage from servomotor	2 Weeks
	4	Check for rust and damage in uncovered parts	2 Weeks
	5	Inspect for foreign matter on floor	2 Weeks
	6	Observation of vibration and noise	2 Weeks
	7	Check for peeling paints	2 Weeks
	8	Check for water leakage from valve seat	1 Year
	9	Check for damage in valve body, seat casing, shaft etc.	1 Year
	10	Observe and record cavitation and pitting	1 Year
	11	Check for tightening of rod and pin of servomotor	1 Year

Equipment	No.	Inspection Items	Interval
	12	Inspect shaft for discoloration and corrosion	3 Years
	13	Check bearing bushes for wear and damage	3 Years
	14	Confirm the bush interior lubrication	3 Years
	15	Check cylinder piston and packing for wear and damage	3 Years
By Pass Valve for I.V.	1	Check for vibration and noise	2 Weeks
	2	Check for water leakage from valve seat	1 Year
	3	Check and record cavitation and pitting	1 Year
	4	Check for damage to valve seat, casing, shaft etc.	1 Year
	5	Check shaft for discoloration and corrosion	3 Years
	6	Check for wear, damage and lubrication in bearing bushes	3 Years
	7	Check servomotor for oil leakage, tightness of rod and pin	1 Year
	8	Check cylinder, piston and packing for wear, damage	3 Years
Wicket Gates	1	Check for damage to wicket gate bodies	1 Year
	2	Record cavitation on mating surface	1 Year
	3	Check clearance of mating surface	1 Year
	4	Look for obstructions to movement of gates	1 Year
	5	Measure and record top and bottom clearances	1 Year
	6	Check for discoloration and corrosion	3-5Years
	7	Check for adequate greasing	3-5Years
	8	Inspect guide bearing and bush for wear	3 Years
	9	Inspect thrust bearing and lines for damages	3-5Years
	10	Replace damaged packing	3-5 Years
Wicket Gate Operating Mechanism	1	Check the grease lubricating condition for wicket gate upper stem guide and thrust bearings	1 Week
	2	Check for water leakage at gate stem	1 Week
	3	Check for grease leakage	1 Week
	4	Inspect for broken shear pin	1 Week
	5	Check rust in wicket gate lever shear pin and link	1 Year
	6	Inspect the locking of nuts	1 Year
	7	Check for damage of external surface	3 Years
	8	Check wicket gate stem and bushes for wear and damage	
	9	Check damage to rubber packing	3 Years
	10	Observe differences in accumulated grease at each bushes and clean them	3 Years
	11	Inspect bearing for wear damage and lubrication	3 Years
	12	Check tightness of rod and pin of the servomotor	1 Year
	13	Check the squeeze of rod and pin of the servomotor	1 Year
	14	Check cylinder for wear and damage	1 Year
	15	Check piston and piston ring for damage	3 Years
	16	Check for damage to packing	3 Years
Shaft Seal	1	Check for water leakage from seal	1 Week
	2	Observe the wear of carbon ring	1 Week
	3	Check housing, cover and carbon ring holder for corrosion	1 Year
	4	Check for quantity of cooling water	1 Year
	5	Check the amount of wear of carbon ring	3 Years
	6	Check for damage to rubber packing and spring	3 Years

Equipment	No.	Inspection Items	Interval
Runner	1	Note vibration and sound	1 Week
	2	Observe and record cavitation pitting	1 Year
	3	Measure clearance	1 Year
	4	Repair cavitation pitting if necessary	3 Years
	5	Check for cracks in runner	3 Years
	6	Measure clearance of wearing ring	5 Years
Turbine Internal Surface	1	Inspect for wear damage in spiral casing	1 Year
	2	Inspect for wear and damage to stay vanes	1 Year
	3	Observe and record cavitation pitting in the draft tube	1 Year
	4	Check for damage to negative pressure side of the jet pump	1 Year
	5	Check facing plate for wear and damage	1 Year
	6	Inspect the bottom ring	1 Year
	7	Remove rust, mud and sand from piping	1 Year
	8	Check the hinge and lock bolt of the manhole cover for rust, corrosion	1 Year
	9	Repaint inner surface if necessary	3-5Years
Turbine External Surface	1	Check for water leakage at dismantling joints of turbine inlet valve	1 Week
	2	Check leakage of spiral casing manhole	1 Week
	3	Confirm the tightness of head cover bolts	1 Week
	4	Check for leakage at the cover	1 Week
	5	Check for leakage at flanges of pit liners and check for foreign matter on platform	1 Week
	6	Inspect rusting at gate ring	1 Week
	7	Observe if there is abnormal noise in draft tube	1 Week
	8	Inspect for oil leakage from servomotor	1 Week
	9	Inspect servomotor for rust and damage	1 Week
Turbine Guide Bearing	1	Check for temperature abnormality	1 Week
	2	Check oil level in lubrication oil tank	1 Week
	3	Check for oil discoloration	1 Week
	4	Check for oil leakage	1 Week
	5	Check for adequate cooling water flow	1 Week
	6	Filter oil if necessary	1 Year
	7	Replace oil if necessary	1 Year
	8	Measure bearing clearances	3-5Years
	9	Clean inside and outside of oil reservoir	3-5Years
Generator Lower Guide Bearing	1	Check for temperature abnormality	1 Week
	2	Check oil level	1 Week
	3	Check for oil discoloration	1 Week
	4	Check for oil leakage	1 Week
	5	Check for adequate cooling water flow	1 Week
	6	Filter oil if necessary	1 Year
	7	Measuring clearance of the bearing	3-5Years
	8	Clean inside and outside of oil reservoirs	3-5Years
Brake Shoes and Brake Ring	1	Check and record the amount of wear of brake shoes	1 Month
	2	Inspect the relationship between the wear and the operating frequency	1 Month
	3	Check the brake ring for any sign of wear and damage	1 Month
	4	Check the brake piston movement	1 Month

Equipment	No.	Inspection Items	Interval
Generator Upper Guide Bearing	1	Check for temperature abnormality	1 Week
	2	Check oil level	1 Week
	3	Check for oil discoloration	1 Week
	4	Check for oil leakage	1 Week
	5	Check for adequate cooling water flow	1 Week
	6	Filter oil if necessary	1 Year
	7	Measure bearing clearances	3-5Years
	8	Clean inside and outside of oil reservoir	3-5Years
Generator	1	Check for the rated amount of cooling water flow in the air cooler	1 Week
	2	Check for water leak from cooling water pipes	1 Month
	3	Check for oil leakage	1 Month
	4	Cleaning of generator air coolers	1 Month
Governor	1	Oil quantity in dash pot	1 Week
	2	Lubricate link and sliding parts	6 Months
	3	Clean oil filters	6 Months
	4	Measure opening and closing time of wicket gate	6 Months
	5	Measure operating time of 77 m and 66 m	1 Year
	6	Check opening position indicator	1 Year
	7	Check for oil leakage at valves and piping	1 Year
	8	Check oil pressure switches for operation	1 Year
	9	Check distributing valves and control valves for operation and oil leakage	3-5Years
Pressure oil Supply System	1	Confirm that pressure and oil level of the pressure tank are within normal range	1 Week
	2	Check for any oil or air leakage from pressure tank	1 Week
	3	Check oil cooler for any leakage	1 Week
	4	Check operation of pumps etc.	1 Week
	5	Check the temperature of oil pumps and motors	1 Week
	6	Check for abnormal noise or vibration	1 Week
	7	Confirm the oil level and temperature of sump tank	1 Week
	8	Check the operation of unloader valve and control valves	1 Week
	9	Check the oil for abnormality, and filter if necessary	6 Months
	10	Confirm the oil pressure level switches operate correctly	6 Months
	11	Clean the filter element	6 Months
	12	Clean strainers	1 Year
	13	Calibrate the pressure gauge	1 Year
	14	Confirm the pressure switches operate correctly	1 Year
	15	Check the operation of safety valves	1 Year
	16	Check the discharge volume of oil pumps	1 Year
Governor Air Compressor	1	Check crank case oil level	Everyday
	2	Check drain valve	Everyday
	3	Cleaning external surface	1 Week
	4	Check for any abnormality of vibration, sound, temperature and current	1 Week
	5	Check for oil leakage	1 Week
	6	Check for belt tightness	1 Month
	7	Check unloaded starting device and crank case oil	3 Months
	8	Clean suction and delivery valves	6 Months
	9	Replacement of lubricating oil	1 Year

Equipment	No.	Inspection Items	Interval
Brake Air Compressor	1	Check the crank case oil level	Everyday
	2	Check drain valve	Everyday
	3	Clean external surface	1 Week
	4	Check for absorbability of vibration, sound, temperature and current	1 Week
	5	Check for oil leakage	1 Week
	6	Check for belt tightness	1 Month
	7	Check unloaded starting device and crank case oil	3 Months
	8	Clean suction and delivery valves	6 Months
	9	Replacement of lubricating oil	1 Year
Cooling Water Pump No.01	1	Check for excessive vibration and noise	1 Week
	2	Check for adequate amount of lubricating oil	1 Week
	3	Measure bearing temperature	1 Week
	4	Clean the outer surface	1 Week
	5	Check packing	1 Week
	6	Change bearing oil	6 Months
	7	Check the oil seal	1 Year
	8	Check the shaft sleeve and impeller	1 Year
Cooling Water Pump No.02	1	Check for excessive vibration and noise	1 Week
	2	Check for adequate amount of lubricating oil	1 Week
	3	Measure bearing temperature	1 Week
	4	Clean the outer surface	1 Week
	5	Check packing	1 Week
	6	Change bearing oil	6 Months
	7	Check the oil seal	1 Year
	8	Check the shaft sleeve and impeller	1 Year
Centralized Grease Lubrication System	1	Check the operating time of distributor	1 Week
	2	Check the operation of hydraulically operated reversing valve	1 Week
	3	Inspect the operation of distributor	1 Week
	4	Check for grease leakage from pipes	1 Week
	5	Check for damage of respective equipment	1 Week
	6	Check the amount of grease in reservoir and stroke can	1 Week
	7	Check the lubricating oil for contamination	1 Week
	8	Check the motor driver grease pump for operation	1 Week
	9	Confirm the lubrication condition of every part	1 Month
	10	Check the operation of the manual lubricating pump	1 Month
	11	Check the operation of the motor driver barrel pump	1 Month
	12	Clean filling part strainer	1 Month
	13	Clean Y-type strainer	1 Month
	14	Charge the lubricating oil in the pump casing	1 Year
Draft Tube Gates	1	Check all the lubricating points for adequate lubrication	1 Month
	2	Check all the bolts and nuts of monorail hoist, gate leaf and lifting beam	1 Month
	3	Check each portion for cracks and deformation	1 Month
	4	Check the wire ropes for broken strands	1 Month
	5	Inspect abnormal noise and vibration during operation	1 Month
	6	Clean the seal rubber portion of gate leaf	1 Month
	7	Check the seal rubber packing for ablation breaking or wear	1 Month
	8	Clean and check for corrosion	1 Month
	9	Lubricate wire ropes	1 Year

Equipment	No.	Inspection Items	Interval
	10	Check for water leakage at full closed position of gate leaf	1 Year
Fire Protection System	1	Confirm the availability of the water in the fire protection tank	Everyday
	2	Measuring and recording of fire extinguisher weights	6 Months
	3	Inspection of fire protection system valves and water tank tubes	6 Months
Drainage Pump No.01	1	Check for excessive vibration and noise	1 Week
	2	Check for adequate amount of lubrication oil	1 Week
	3	Measure thrust bearing temperature	1 Week
	4	Adjust tightness of the gland	1 Week
	5	Clean the outer surface	1 Week
	6	Change ball and roller bearing oil	3 Months
	7	Check inner and outer race surface	3 Months
	8	Inspect gland packing for water leakage	3 Months
	9	Check under water sliding bearing	1 Year
	10	Check the sliding surfaces of mechanical seal	1 Year
	11	Check the shaft sleeve	1 Year
	12	Check the O – ring	1 Year
	13	Check the casing wear ring	1 Year
	14	Check the entire impeller	1 Year
	15	Check the coupling bolts and rubber rings	1 Year
	16	Check the shaft sleeve	2 Years
	17	Replace the O - ring	2 Years
	18	Measure the sliding surface between the impeller and casing wear ring	2 Years
Drainage Pump No.02	1	Check for excessive vibration and noise	1 Week
	2	Check for adequate amount of lubrication oil	1 Week
	3	Measure thrust bearing temperature	1 Week
	4	Adjust tightness of gland packing	1 Week
	5	Clean the outer surface	1 Week
	6	Change ball and roller bearing oil	3 Months
	7	Check inner and outer race surface	3 Months
	8	Inspect gland packing for water leakage	3 Months
	9	Check underwater sliding bearing	1 Year
	10	Check the sliding surfaces of mechanical seal	1 Year
	11	Check the shaft sleeve	1 Year
	12	Check the O - ring	1 Year
	13	Check the casing wear ring	1 Year
	14	Check the entire impeller	1 Year
	15	Check the coupling bolts and rubber rings	1 Year
	16	Check the shaft sleeve	2 Years
	17	Replace the O - ring	2 Years
	18	Measure the sliding surface between the impeller and casing wear ring	2 Years
Station Service Air Compressor	1	Check oil level and pressure	Everyday
	2	Check drain valve	Everyday
	3	Check for leakage of air and oil	1 Week
	4	Check for abnormal noise and vibrations	1 Week
	5	Clean external surface	1 Week
	6	Check the safety valve	1 Week
	7	Check the bolts and nuts for tightness	1 Month

Equipment	No.	Inspection Items	Interval
	8	Check the belts for tightness	1 Month
	9	Clean the air filters	3 Months
	10	Change lubricating oil	3 Months
	11	Clean oil strainer	3 Months
	12	Check and adjust the oil pressure adjustment valve if necessary	6 Months
	13	Clean suction and delivery valves	6 Months
	14	Check for wear of valve springs and plates	6 Months
	15	Change element of air filter	6 Months
Hoisting Mechanical	1	Coupling bolts, motor, break bolts and operation	1 Month
	2	Unusual noise and vibration	1 Month
	3	Wear of break lining and slack of bolts for gear box and bearings	1 Month
	4	Wear of drum groove (24% of the wire rope diameter)	1 Month
	5	Condition of oil and damage of drum	1 Month
	6	Reduction of wire rope diameter (7%)	1 Month
	7	Cut lines and joints of the wire rope, and setting condition of the wire rope clamps.	1 Month
	8	Bush, key plate, pin of the hook block and rotation of the hook	1 Month
	9	Damage to the hook, hook screw and hook nut	1 Month
Over Head Travel Crane	1	The condition of the runway	1 Week
	2	The rail supports of the trolley	1 Week
	3	The condition of the wire rope passing places	1 Week
	4	Unusual noise, temperature rise and vibration	1 Week
	5	Performance of the brake	1 Week
	6	Performance of the overwinding protectors	1 Week
	7	Meander of trolley and saddles	1 Week
	8	Performance of the controls	1 Week
	9	Hook, rope sheave, drum, cracks and deformation in girders, and welded parts	1 Week
Runway and Traveling Mechanical Equipment of O.H.T.C.	1	Set bolt, sole plate, stoppers and rail clip of the runway	1 Week
	2	Compiling bolts, motor bolts and operation	1 Week
	3	Oil leakage, unusual noise of gear box	1 Week
	4	Slack of brake lining wheels and bearing case	1 Week
	5	Wear of brake lining wheels and bearing case	1 Week
	6	Condition of oiling	1 Week
Traversing Mechanical Equipment for O.H.T.C.	1	Wear of wheel lubrication of the bearing and deformation and slack of the end plates	1 Month
	2	Wear of the lining, torque adjustment device	1 Month
	3	Operation of the brake lever and brake oil	1 Month
	4	Deformation of the brake lever and pin, and brake oil	1 Month
	5	At motor and brake bolts, unusual noise and vibration of the gear box	1 Month
Structure of O.H.T.C.	1	Bending of the structure of girder and saddle	1 Month
	2	Check tightness of girder and saddle joining bolts	1 Month
	3	Check tightness of joining bolts of the trolley	1 Month
Electrical and Mechanical Equipment O.H.T.C.	1	Runway	1 Year
	2	Traversing rail	1 Year
	3	Hook	1 Year
	4	Rust and painting	1 Year

Equipment	No.	Inspection Items	Interval
Diesel Engine and Generator	1	Check for lubrication oil leakage	1 Month
	2	Check for operation of oil heater	1 Month
	3	Check engine oil level	1 Month
	4	Check hydraulic governor oil level	1 Month
	5	Check for cooling air leakage	1 Month
	6	Check for radiator air restriction	1 Month
	7	Check for operation of coolant heater	1 Month
	8	Check hose and connections	1 Month
	9	Check coolant level	1 Month
	10	Check Antfreeze and DCA connection	1 Month
	11	Check belt condition and tension	1 Month
	12	Check air intake for leakage	1 Month
	13	Check for air cleaner restrictions	1 Month
	14	Check fuel oil leakage	1 Month
	15	Check fuel level	1 Month
	16	Check fuel transfer pump	1 Month
	17	Check exhaust restriction	1 Month
	18	Drain condensate trap	1 Month
	19	Change fuel flow filter	6 Months
	20	Change bypass filter	250 hours
	21	Change engine oil	250 hours
	22	Change hydraulic governor oil	250 hours
	23	Check heat exchanger	250 hours
	24	Change DCA water filter	250 hours
	25	Check piping and connection	250 hours
	26	Clean crank case breather	250 hours
	27	Clean or change air cleaner element	250 hours
	28	Check governor linkage	250 hours
	29	Check fuel lines and connections	250 hours
	30	Drain sediment from tank	250 hours
	31	Change fuel filters	250 hours
	32	Check fan hub, drive pulley, Water pump	250 hours
	33	Clean cooling system	1 Year
	34	Change float tank breather	1 Year
	35	Tighten exhaust manifold and turbo charger cap screw	1 Year
	36	Check for tightness of mounting hardware	1 Year
	37	Clean engine	1 Year
Air Conditioner and Ventilation System	1	Check belt and bearing for wear	1 Month
	2	Check belt tension	1 Month
	3	Check pulley alignment	1 Month
	4	Check wheel balance condition	1 Month
	5	Check for air leakage from panels	1 Month
	6	Check for proper refrigeration charge	1 Month
	7	Inspect refrigeration charge	1 Month
	8	Inspect the filters	1 Month
	9	Clean the units	1 Month
	10	Inspect the ventilation fan for abnormalities	1 Month
	11	Check for obstructions of the ventilation	1 Month
	12	Clean the filters	1 Month
	13	Inspect bearing, relubricate or replace if necessary	1 Year

2. MAJOR OVERHAUL ITEMS IN CANYON HYDROPOWER STATION

2.1 Hydro turbine

- Dewatering the hydro turbine
- Visual inspection of cavitation damage of the runner
- Visual inspection of the wicket gate and the upper facing plate
- Cleaning and lubricating mechanism of the wicket gate
- Inspection of the wicket gate clearance
- Disassembling the shaft seal
- Changing all the O-rings, the corroded nuts and bolts in the shaft seal
- Visual inspection of the draft tube and the spiral case
- Polishing the damaged air admission pipes
- Welding the inlet valve and the bypass valve
- Measuring the clearance between the main shaft and the turbine guide bearing
- Filtering oil in the bearing
- Oil inspection for the bearing oil (about flash point, viscosity and acid)
- Cleaning oil filter in the governor
- Filtering oil in the governor
- Oil inspection for the governor oil (flash point, viscosity and acidity)

2.2 Generator

- Cleaning the stator and the rotor with cloths and wooden sticks
- Visual inspection of the end winding in the stator
- Measuring insulation resistance of the stator and the rotor
- Disassembling and cleaning the PGM and the exciter
- Measuring insulation resistance of the PGM and the exciter
- Filtering the upper and lower guide bearing oils
- Oil inspection for the upper and lower bearing oils (flash point, viscosity and acidity)

2.3 Transformer

- Filtering the transformer oil
- Oil inspection for the upper and lower bearing oils (water content, sludge and acidity)

2.4 12.5kV OCB

- Visual inspection
- Check of the oil level

2.5 Instrument transformers (CT and VT)

- Cleaning the transformers
- Measuring insulation resistance of the instrument transformers

2.6 132kV OCB

- Cleaning the OCB
- Check of oil level

2.7 132kV line isolator and 132kV line earth switch

- Visual inspection of the contact and mechanisms
- Lubricating the mechanism

2.8 Cooling water system

- Disassembling the cooling water pumps
- Visual inspect of the cooling water pipe lines
- Cleaning the pipe line with compressed air and high pressure water
- Cleaning strainers of the system

APPENDIX C-5
電気機械設備に対する
点検項目と保守マニュアル例

1. INSPECTION ITEMS AND INSPECTION FREQUENCY

The items and frequencies of the periodic inspection and overhaul to be carried out for Laxapana Complex are introduced here. If the equipment is operated under hard conditions, it is desirable to shorten the interval between inspections by one year. Bold-faced inspections are important and the related manuals are provided in Section 2 “Inspection Manual”.

1.1 Periodic Inspection

(1) Hydraulic turbine

1) Frequency of inspection: Once / 3 years

2) Inspection items:

- Dewatering of spiral case and draft tube
- Visual check of each component part in hydraulic turbines
- Check for looseness, discoloration, smell, cracks, erosion, peeling paint, wear, scuffing, rust, water leakage, oil leakage, clogged piping and gaps
- Cleaning
- Check for vibration and unusual sound
- Packing check (groove check and replacement)
- Valve check (operation test and disassembly inspection)
- Oil check
  Oil filtering
  Oil quality diagnosis (viscosity, flash point, acidity and color)
- Non-destructive inspection of shear pin and runner (liquid penetrant test or magnetic particle test)
- Check of setting values and secular change
  Servomotor stroke versus wicket gate opening (Francis turbine)
  Servomotor stroke versus needle and deflector openings (Pelton turbine)
  Deflector servomotor stroke versus needle servomotor stroke (Pelton turbine)
  Squeeze
  Gap
  Oil level
  Leakage water quantity
- Characteristics test of hydraulic turbine
  Opening and closing test of wicket gates
  Automatic start and stop test
  Measurement of shaft run-out and vibration
- Relay test (confirmation of setting value and operation test)
- Calibration of instrument

(2) Inlet valve

1) Frequency of inspection: Once / 3 years

2) Inspection items:

- Visual check of each component part of inlet valve
- Check for looseness, discoloration, cracks, erosion, peeling paint, wear, scuffing, rust, water leakage, oil leakage, clogged piping and gaps
- Cleaning
- Check of associated valve (operation test and disassembly inspection)

- Opening and closing test for inlet valve
- Measurement of leakage water quantity
- Relay test (confirmation of setting value and operation test)

(3) Speed governor

1) Frequency of inspection: Once / 3 years

2) Inspection items:

- Visual check of each component part of speed governor
- Check for looseness, peeling paint and oil leakage
- Cleaning
- **Measurement of insulation resistance of cubicle heater, permanent magnetic generator, wiring, transformer and governor**
- Calibration of balance meter, gate position meter, speed setting meter, speed meter and pressure gauge
- Characteristic test of permanent magnetic generator, speed signal generator, amplifier, potentiometer (value confirmation between output and input)
- Operation test of limit switch, control motor for speed setting and gate position
- Characteristic test of governor
  Opening and closing test of wicket gate
  Characteristic test of main distributing valve
  Characteristic test of frequency detecting circuit
  Characteristic test of converter
  Characteristic test of rigid and flexible returns
  Characteristic test of speed adjusting device (abbreviated as 65F) and load limiting device (abbreviated as 65P)
  Characteristic test of dead band
  Indicial response test
  Damping characteristic
  Step control test
  Automatic start and stop test

(4) Generator

1) Frequency of inspection: Once / 3 years

2) Inspection items:

- Visual check of air housing, stator, rotor, air cooler, bearings, bracket, brake, NGR and so on.
- Check for looseness, discoloration, smell, cracks, peeling paint, wear, scuffing, rust, water leakage, oil leakage, clogged piping and gaps
- Replacement of consumables such as gaskets
- Cleaning
- Valve check (operation test and disassembly inspection)
- Oil check
  Oil filtering
  Oil quality diagnosis (viscosity, flash point, acidity and color)
- Characteristic test of generator
  Measurement of insulation resistance
  Confirmation of polarization index
  Measurement of shaft voltage
  Measurement of vibration under operation

Sequence and operation test
Automatic start and stop test
- **Relay test (confirmation of setting value and operation test)**

(5) Excitation equipment

1) Frequency of inspection: Once / 3 years

2) Inspection items:

- Visual check of excitation equipment
- Check for looseness, discoloration, smell, cracks, peeling paint, wear, scuffing, rust and gaps
- Replacement of consumables such as gaskets
- Cleaning
- Check size of blush and blush holder
- Characteristic test of excitation system
  Measurement of insulation resistance
  Characteristic test of voltage detecting circuit
  Indicial response test
  Manual and remote operation and sequence test
  Individual test for automatic voltage regulator (AVR)
- Relay test (confirmation of setting value and operation test)

(6) Generator transformer

1) Frequency of inspection: Once / 6 years

2) Inspection items:

- Visual check of tank, bushing, tap changer, conservator and so on
- Check for looseness, discoloration, smell, cracks, rust, water leakage, oil leakage and clogged piping
- Lubrication of operation linkage of on-load tap changer
- Replacement of consumables such as contact of on-load tap changer
- Cleaning
- Calibration of dial thermometer
- Oil check
  Oil filtering
  Oil quality diagnosis (viscosity, flash point, acidity, color and gas diagnosis of H_2, N_2, HC, C_2H_2, CO, CO_2)
- Characteristic test of generator transformer
  Measurement of insulation resistance
  Measurement of current of auxiliary equipment
  Sequence and operation test
- Relay test (confirmation of setting value and operation test)

(7) Switchgear

1) Frequency of inspection:

- Once / 3 years for oil circuit breaker, air circuit breaker, magnetic circuit breaker and vacuum circuit breaker
- Once / 6 years for gas circuit breaker

2) Inspection items:

- Visual check of main conductor and operation structure
- Check for looseness, discoloration, smell, cracks, rust, oil leakage and gas leakage
- Lubrication of operation linkage
- Adjustment of moving parts
- Replacement of consumables such as gaskets
- Cleaning
- Calibration of safety valve
- Characteristic test of switchgear
  Measurement of insulation resistance
  Manual and remote operation test
  Sequence and operation test
- Relay test (confirmation of setting value and operation test)

(8) Control and protection equipment

1) Frequency of the inspection for the whole equipment: As needed

2) Frequency of inspection of component parts is shown for reference.

- Control equipment
  Once / 3 years for analogue measurement part
  Once / year for power source
  Once / 12 years for instrument
  Once / 6 years for other parts
- Protection equipment
  Once / 6 years for digital type (numerical type)
  Once / 4 years for non-digital type with automatic monitoring system
  Once / 2 years for non-digital type without automatic monitoring system

3) Inspection items:

- Visual check and cleaning (indicators, meters and relays on main control equipment, auxiliary and protection equipment)

- Characteristic tests
  Measurement of insulation resistance (meters, relays, current & voltage circuits)
  Burden check (indicators, meters, relays, current & voltage circuits)
  Sequence test of direct current (protection system)
  Overall sequence and operation test (turbine, generator with auxiliary equipment)

1.2 Overhaul

(1) Hydraulic turbine

1) Overhaul frequency for Francis and Pelton turbines is shown below.

- Once / 16 - 19 years for turbine less than 20MW
- Once / 15 – 18 years for turbine from 20MW to less than 40MW
- Once / 14 – 16 years for turbine over 40MW

2) Inspection items:

The following inspections are carried out in addition to the periodic inspection items.

- Full dewatering and full disassembly
- Non-destructive inspection (liquid penetrant inspection or magnetic particle inspection: coupling flange, bearing metal surface, liner, shear pin and wicket gate root)
- Characteristic test with the whole equipment
  Wicket gate operation with and without water
  Main bearing heat test
  Output versus gate (or needle) opening test
- Report on assembly (records of gap, level value, and leveling and adjusting method)

(2) Inlet valve

1) Overhaul frequency: Twice the above-indicated frequency for hydraulic turbines

2) Inspection items:

The following inspections are carried out in addition to the periodic inspection items.

- Full dewatering and full disassembly
- Replacement of packing
- Characteristic test (opening and closing test with and without water)

(3) Speed governor

1) Overhaul frequency: half of the above-indicated frequency for hydraulic turbines

2) Inspection items:

The following inspections are carried out in addition to the periodic inspection items.

- Measurement of resistance, voltage and waveform
- Operation test of load limiting device, locking device and distributing valve
- Inspection of servomotor
  Disassembly inspection
  Replacement of packing
  Measurement of relation between auxiliary and main servomotor strokes
  Measurement of opening and closing force of main servomotor
  Measurement of opening and closing time
- Total characteristic test of hydraulic turbine and governor
  Measurement of speed droop
  Measurement of dead band
  Indicial response test
  Measurement of frequency control range
  Characteristic test of amplifier and feedback system
  Load rejection test

(4) Generator

1) Overhaul frequency: Same as the frequency for hydraulic turbines

2) Inspection items:

The following inspections are carried out in addition to the periodic inspection items.

- Disassembly of generator including removal of rotor
- Visual check of all wedges and coils in stator
- Disassembly inspection of air cooler and bearing
- Liquid penetrant test for bearing
- Characteristic test of generator
  Voltage sharing test on rotor（coil impedance test on rotor）
  Bump test after assembly
  Balance adjustment
  Load test
- Report on assembly (records of gap, level value, and leveling and adjusting method)

(5) Excitation equipment

1) Overhaul frequency:

Same as the frequency for the generator for excitation equipment
Half of the frequency for the generator for AVR

2) Inspection items:

The following inspections are carried out in addition to the periodic inspection items.

- Disassembly of exciter
- Visual check of exciter, field circuit breaker, cubicle (controller and exciter transformer) and AVR
- Characteristic test (recommended by manufacturer)

(6) Generator transformer

1) Overhaul frequency: As needed

Transformer should be overhauled, whenever an abnormal component value of inflammable gas in tank oil is observed by oil gas diagnosis.

- Once / 6 years or 50,000 operations for on-load tap changer

Same as the frequency of generator

2) Inspection items:

The following inspections are carried out in addition to the periodic inspection items.

- Drainage of oil from tank
- Visual check of transformer interior (coil, insulating paper and so on)
- Degassing of oil and oil-filling to tank

(7) Switchgear

1) Overhaul frequency:

- Once / 6 years or frequency recommended by manufacturer for oil circuit breaker and magnetic circuit breaker

- Once / 12 years or frequency recommended by manufacturer for air circuit breaker, gas circuit breaker and vacuum circuit breaker

2) Inspection items::

The following inspections are carried out in addition to the periodic inspection items.

- Disassembly of safety valve, main contact and operation linkage
- Replacement of operation oil

(8) Control and protection equipment

1) Overhaul frequency: As needed

2) Inspection items:

The following inspections are carried out in addition to the periodic inspection items.

- **Load rejection test**

2. INSPECTION MANUAL

2.1 Inspection manual of periodic inspection

(1) Servomotor stroke versus wicket gate opening (Francis)

1) Purpose:

a) To measure correlation between servomotor stroke and wicket gate opening.
b) To check the difference between the measured value and original setting value.
c) To confirm the secular change.

2) Date: _____

3) Place: Unit _____ in _____ Hydropower Station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Commander			
2. Safety director			
3. Servomotor stroke			
4. Wicket gate opening			
5. Operator			

5) Measurement conditions:

a) This measurement is performed in the periodic inspection
b) This measurement is a dry test
c) Equipment to be locked for the test and other conditions are as follows:
- Equipment to be locked:
  No electrical lock
  Mechanical lock for inlet valve
- Other conditions:
  None

6) Measurement procedure:

a) Wicket gate servomotor is operated from governor.
b) The servomotor is opened from closing position to 100% opening position. The wicket gate opening should be measured every 10% of the servomotor stroke.
c) Same procedure is applied to the opening measurement from 100% opening to closing.
d) The wicket gate opening is measured at the center of the gate.
e) Operation direction (opening or closing) of the servomotor should not be changed during the measurement.
f) For safety, the main oil supply valve should be fully closed when the wicket gate opening is measured. Also, it should be confirmed that there is no residual pressure at the governor distribution valve. The servomotor stopper should be used during the measurement, if possible.

7) Measurement schedule:

The following time is shown for reference.

8:00 Meeting before the measurement
Prepare for the measurement and lock the equipment shown in item 5)-c)
9:00 Operator operates the servomotor
Set the servomotor stroke to 10% opening
Close the oil supply valve and set the servomotor stopper
Measure the wicket gate opening
9:15 Next measurement is repeated. ……

8) Table for measurement:

Refer to the table “Servomotor stroke vs wicket gate opening”

9) Judgment criteria:

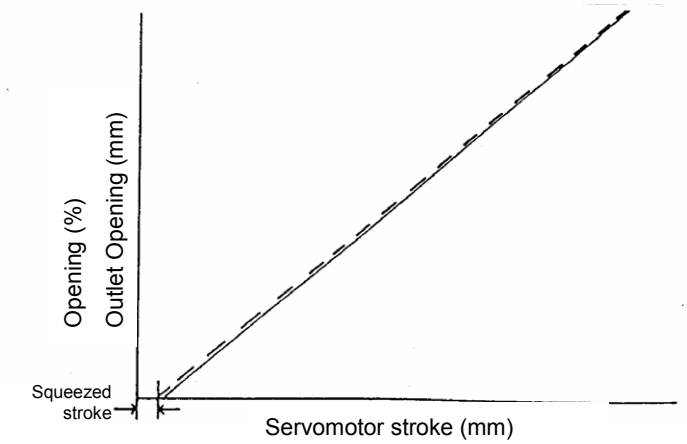
Less than ±1.5% of average stroke at 100% wicket gate opening (for reference)

Servomotor Stroke VS Wicket Gate Opening

Record

	Servomotor Stroke (mm) \ No. of Wicket Gate (mm)	Wicket Gate Opening (mm) ~	~	~	~	~	Average
Open Direction							
Close Direction							

Remarks:
a. Design Valve of 100% of Gate Opening (Outlet Opening) _____ mm Servomotor Stroke _____ mm
b. Squeezed Stroke _____ mm
c. Oil temperature _____ °C



(2) Servomotor stroke versus needle and deflector openings (Pelton)

1) Purpose:

a) To measure correlation between the needle servomotor stroke and needle opening.
b) To measure correlation between the deflector servomotor stroke and deflector opening.
c) To check the difference between the measured value and the original setting value.
d) To confirm the secular change.

2) Date: _____

3) Place: Unit _____ in _____ Hydropower Station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Commander			
2. Safety director			
3. Deflector servomotor stroke			
4. Deflector opening			
5. Needle servomotor stroke			
6. Needle opening			
7. Operator			

5) Measurement conditions:

a) This measurement is performed in the periodic inspection
b) This measurement is a dry test
c) Equipment to be locked for the test and other conditions are as follows:
- Equipment to be locked:
  No electrical lock
  Mechanical lock for inlet valve
- Other conditions:
  None

6) Measurement procedure:

a) Needle servomotor is operated from governor.
b) The needle servomotor is opened from closing position to 100% opening position. The needle gate opening should be measured every 10% of the needle servomotor stroke.
c) Same procedure is applied to the opening measurement from 100% opening to closing.
d) The above-mentioned procedure is applied to measurement of “deflector servomotor stroke and deflector opening”.
c) Operation (opening or closing) direction of the servomotors should not be changed during the measurement.
d) For safety, the main oil supply valve should be fully closed when the needle opening is measured. Also, it should be confirmed that there is no residual pressure at the governor distribution valve. The servomotor stopper should be used during the measurement, if possible.

7) Measurement schedule:

Refer to the measurement schedule of “(1) Servomotor stroke versus wicket gate opening”

8) Table for measurement:

Refer to the table “Servomotor stroke and needle opening” and “Servomotor stroke and deflector opening”.

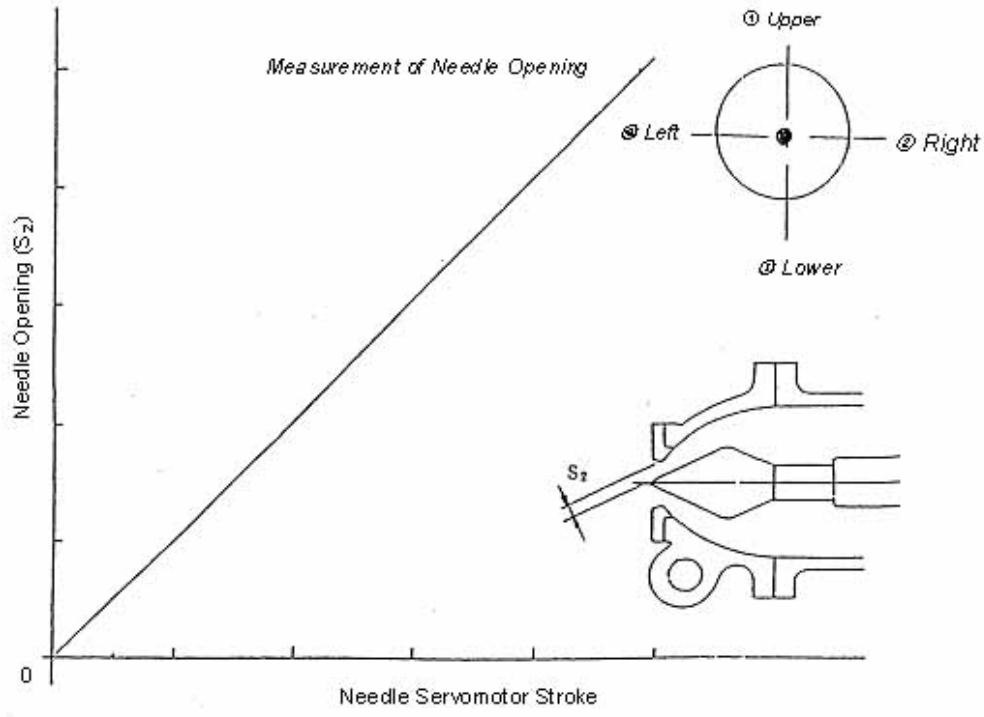
9) Judgment criteria:

The difference of each servomotor stroke is less than ±2 mm of mean values for needle opening and deflector opening (for reference).

Servomotor stroke and needle opening

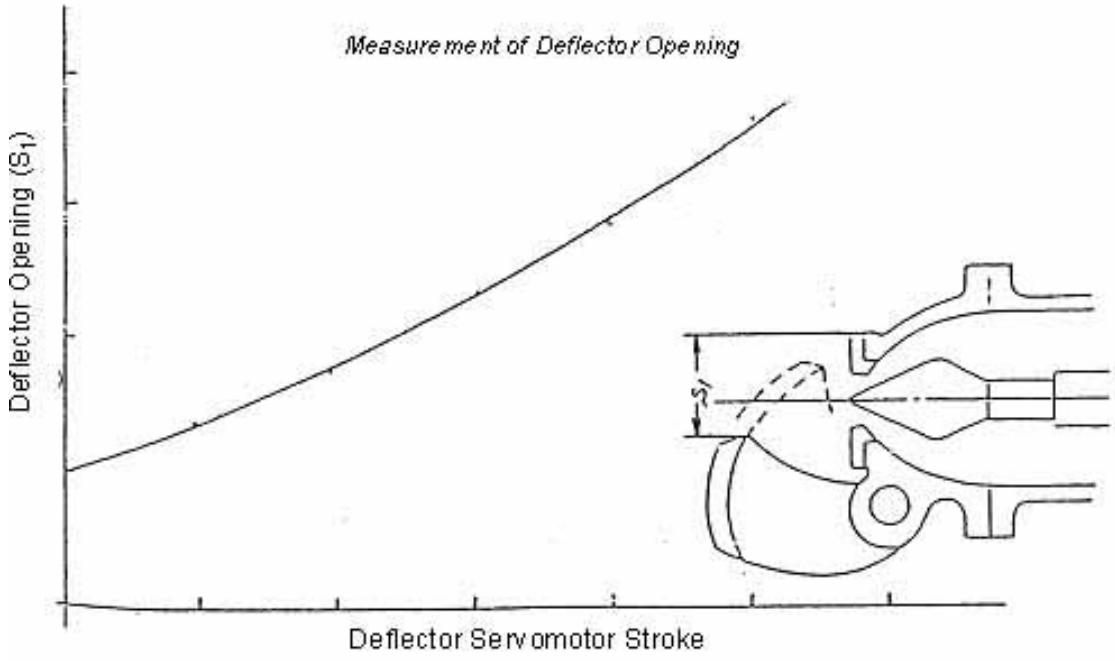
Needle Servomotor Stroke (mm)												
Needle Opening (mm)	①											
	②											
	③											
	④											

Remarks: To be measured for all needles



Servomotor stroke and deflector opening

Deflector Servomotor Stroke (mm)													
Deflector Opening (mm)	No. 1												
	No. 2												
	No. 3												
	No. 4												



(3) Deflector servomotor stroke versus needle servomotor stroke (Pelton)

1) Purpose:

a) To measure correlation between the deflector servomotor stroke and needle servomotor stroke.
b) To check the difference between the measured value and the designed value.
c) To confirm the secular change.

2) Date: _____

3) Place: Unit _____ in _____ Hydropower Station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Commander			
2. Safety director			
3. Deflector servomotor stroke			
4. Needle servomotor stroke			
5. Operator			

5) Measurement conditions:

a) This measurement is performed in the periodic inspection
b) This measurement is a dry test
c) Equipment to be locked for the test and other conditions are as follows:
- Equipment to be locked:
  No electrical lock
  Mechanical lock for inlet valve
- Other conditions:
  None

6) Measurement procedure:

a) Deflector and needle servomotors are operated from governor.
b) The deflector servomotor is opened from closing position to 100% opening position. The needle servomotor stroke should be measured every 10% of the deflector servomotor stroke.
c) Same procedure is applied to the opening measurement from 100% opening to closing.
d) Operation direction (opening or closing) of the servomotor should not be changed during the measurement.

7) Measurement schedule:

Refer to the measurement schedule of "(1) Servomotor stroke versus wicket gate opening"

8) Table for measurement:

Refer to the table "Deflector stroke vs needle stroke"

9) Judgment criteria:

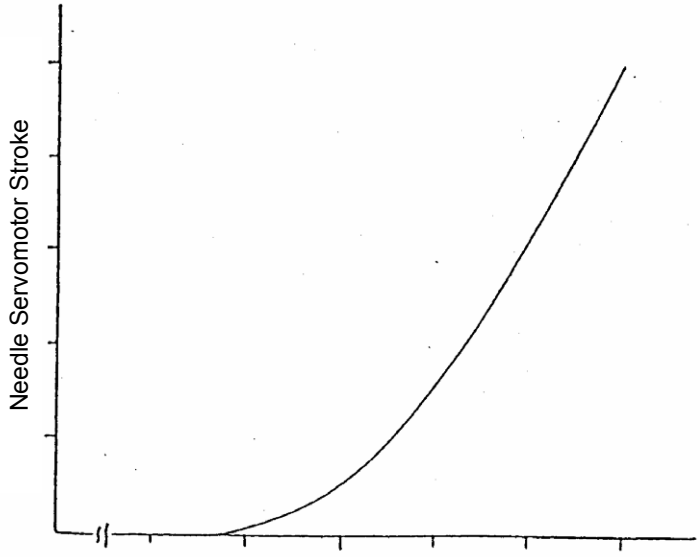
Less than ±1 % of designed value (for reference)

Deflector Stroke VS Needle Stroke

Deflector Servomotor Stroke (mm)	Design Values of Needle Servomotor Stroke (mm)	Measured Values of Needle Servomotor Stroke (mm)			
		No.1	No.2	No.3	No.4

Remarks:

*Oil pressure*_____ ℃



(4) Characteristic test of main distributing valve in governor

1) Purpose:

To confirm the capacity of the main distributing valve and the oil pressure lap through the measurement of the distributing valve lift and the opening & closing velocities of the main servomotor.

2) Date: _____

3) Place: Unit _____ in _____ Hydropower Station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Commander			
2. Safety director			
3. Lift of distributing valve			
4. Main servomotor stroke			
5. Time			
6. Operator			

5) Measurement conditions:

a) This measurement is performed in the periodic inspection.
b) This measurement is a dry test or wet test.
c) Equipment to be locked for the test and other conditions are as follows:
- Equipment to be locked:
  No electrical lock
  Mechanical lock for the inlet valve
- Other conditions:
  Oil temperature in the servomotor should be adjusted nearly equal to that in the oil pressure tank.
  The oil pressure of pressure tank should be within the normal oil pressure range during measurement.
  The safety director should prohibit any person from entering the spiral case and turbine pit during the operation of the wicket gates (or deflectors, needles, runner vanes).

6) Measurement procedure:

a) The feedback mechanism should be disconnected from the main servomotor to prevent the transmission of a feedback signal to the main distributing valve.
b) After confirming that the distributing valve is located at the neutral position, the opening and closing velocity of the main servomotor to each valve lift should be measured.
c) Measurement should be performed after finishing the adjustment and setting of main servomotor stoppers corresponding to full closing and full opening positions.

7) Measurement schedule:

The following schedule is shown for reference.

8:00 Meeting before the measurement
Prepare for the measurement and lock the equipment shown in item 5)-c)
9:00 Operator operates the distributing valve to measure the oil pressure lap.
Set the lift of the distributing valve and measure the velocity of the main servomotor.
9:15 Next measurement is repeated. ……

8) Table for measurement: Refer to the table “Characteristic Test of Main Distributing Valve”

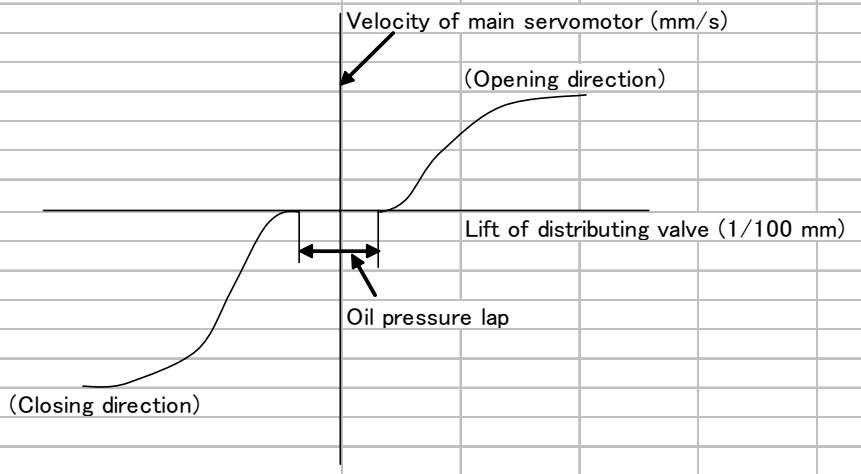
9) Judgment criteria:

a) The proper oil pressure lap of main distributing valve should be confirmed.
b) The main servomotor velocity should have a sufficient margin for the required servomotor velocity for load rejection.

Opening direction					
	Lift of distributing valve (1/100 mm)				
	Main servomotor stroke (mm)				
	Time (s)				
	Velocity of main servomotor (mm/s)				
Closing direction					
	Lift of distributing valve (1/100 mm)				
	Main servomotor stroke (mm)				
	Time (s)				
	Velocity of main servomotor (mm/s)				

Remarks:

a) Full stroke of main servomotor _____ mm
b) Maximum lift of distributing valve _____ mm
c) Stroke of throttle valve closing _____ mm
opening _____ mm
d) Oil temperature _____ ℃



(5) Characteristic test of frequency detecting circuit

1) Purpose:

To confirm the linearity and the gain to frequency of the output of the frequency detecting circuit.

2) Date: _____

3) Place: Unit _____ in _____ Hydropower Station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Commander			
2. Safety director			
3. Frequency			
4. Output (V or R)			
5. Operator			

5) Measurement condition:

a) This measurement is performed in the periodic inspection.
b) This measurement is a dry test.
c) Equipment to be locked for the test and other conditions are as follows:
   - Equipment to be locked:
     Mechanical lock for the inlet valve
     The electrical system of the governor should be disconnected from the mechanical system before the measurement.
     The control pressure oil system should be isolated from the servomotor by means of the stop or main valve.

6) Measurement procedure:

a) The rated frequency should be input into the frequency detecting circuit through a test power generating set or a variable frequency generating set. The position of the speed adjustment device (abbreviated as 65F) should be confirmed when the output voltage or current of the frequency detecting circuit becomes zero.
b) Holding the speed adjustment device (65F) at the above position, the output voltage or current of the frequency detecting circuit should be measured while changing the input frequency.
c) The variation range of the frequency should be within the control range of the speed adjustment device (65F).

Note: An example of a test circuit for the characteristics test of the frequency detecting circuit is shown in the attached table.

7) Measurement schedule:

The following schedule is shown for reference.

8:00 Meeting before the measurement
Prepare for the measurement and lock the equipment shown in item 5)-c)
9:00 Operator operates a test power generating set or a variable frequency generating set.
Measure the output voltage or current.
9:15 Next measurement is repeated. ……

8) Table for measurement:

Refer to the table “Characteristic Test of Speed Detecting Device for Governor”

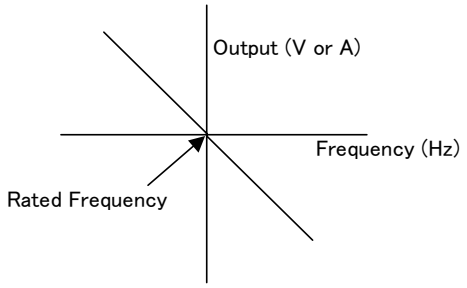
9) Judgment criteria:

a) The output of the frequency detecting circuit should have linearity and a satisfactory gain to frequency .

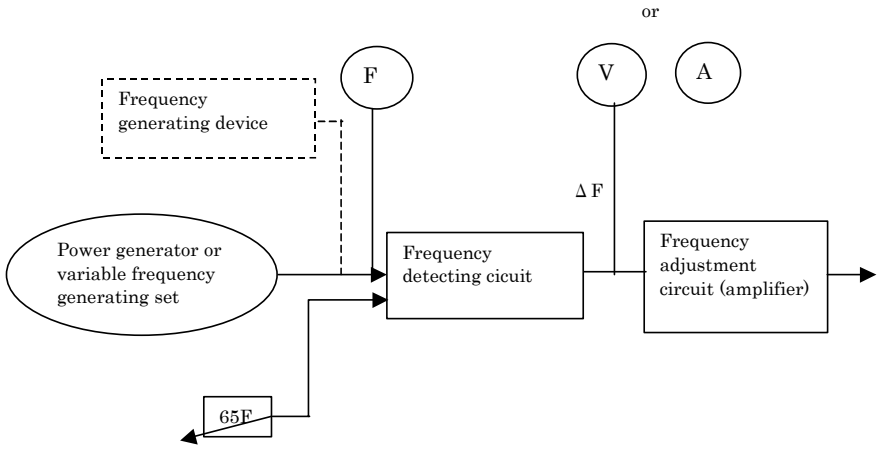
Characteristic Test of Frequency Detecting Circuit for Governor

Frequency (Hz)						
Output Voltage (V)						
or Output Current (A)						

Note: Setting of the speed adjustment device (abbreviated as 65F)_____



An example of a test circuit for characteristic test of frequency detecting circuit



(6) Characteristic test of converter in governor

1) Purpose:

To confirm the characteristics of the converter that converts the electrical signal into the oil pressure.

2) Date: _____

3) Place: Unit _____ in _____ Hydropower Station

4) Assigned persons:

Measurement points	Communication	Name	Note
1. Commander			
2. Safety director			
3. Converter input			
4. Converter movement			
5. Operator			

5) Measurement conditions:

a) This measurement is performed in the periodic inspection.
b) This measurement is a dry test.
c) Equipment to be locked for the test and other conditions are as follows:
- Equipment to be locked:
  No electrical lock
  Mechanical lock for the inlet valve
  The control pressure oil system should be isolated from the servomotor by means of the stop or main valve.

6) Measurement procedure:

a) Opening and closing movement of the converter according to the input voltage or current should be measured.
b) If it is difficult to directly measure the movement, the relation between converter input and opening / closing velocity of the auxiliary servomotor should be measured. In this case, the primary distributing valve should be held at its neutral position.

7) Measurement schedule:

The following schedule is shown for reference.

8:00 Meeting before the measurement
Prepare for the measurement and lock the equipment shown in item 5)-c).
9:00 Operator operates a converter input.
Measure the converter output.
9:15 Next measurement is repeated. ……

8) Table for measurement:

Refer to the table “Characteristic Test of Converter for Governor”

9) Judgment criteria:

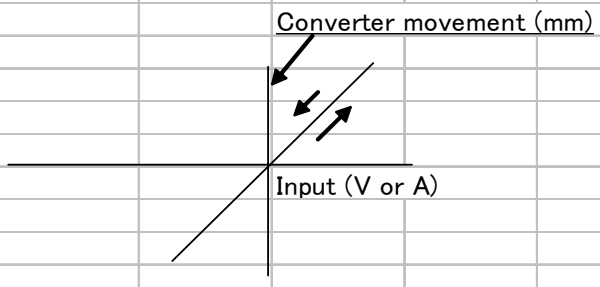
a) The characteristics of the converter should have linearity and fewer hysterics.
b) The primary distributing valve should have the proper oil pressure lap, and the auxiliary servomotor should have sufficient velocity within the specified input range of the converter.
c) The auxiliary servomotor should have the closing tendency with the zero input of converter.

Characteristic Test of Converter for Governor

(1) Characteristic test when the converter movement can be directly measured.

Opening direction				
Converter input voltage (V) or current (A)				
Converter movement (mm)				
Closing direction				
Converter input voltage (V) or current (A)				
Converter movement (mm)				

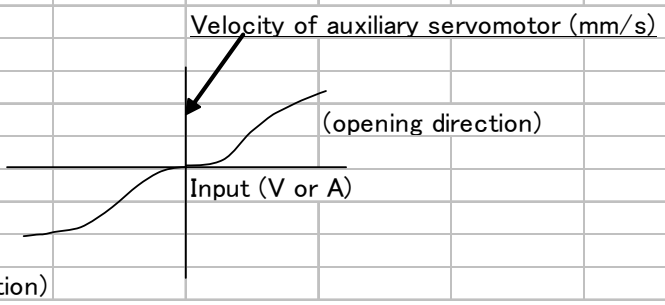
Note: Oil pressure _____℃



(2) Characteristic test when the converter movement can not be directly measured.

Opening direction				
Converter input voltage (V) or current (A)				
Velocity of auxiliary servomotor (mm/s)				
Closing direction				
Converter input voltage (V) or current (A)				
Velocity of auxiliary servomotor (mm/s)				

Note: Oil pressure _____℃



(7) Characteristic Test of Rigid and Flexible Returns

1) Purpose:

To confirm that the speed droop, temporary speed droop and time constant of the flexible return (damping) satisfy the specifications.

2) Date: _____

3) Place: Unit _____ in _____ Hydropower Station

4) Assigned persons:

Measurement points	Communication	Name	Note
1. Commander			
2. Safety operator			
3. Frequency			
4. Auxiliary servomotor stroke			
5. Setup scale of rigid return			
6. Setup scale of flexible return			
7. Voltage of flexible return			
8. Operator			

5) Measurement conditions:

a) This measurement is performed in the periodic inspection.
b) This measurement is a dry test.
c) Equipment to be locked for the test and other conditions are as follows:
- Equipment to be locked:
  No electrical locks
  Mechanical lock for inlet valve

6) Measurement procedure:

6-1) Rigid return

a) The flexible return should be removed from the closing loop including the auxiliary servomotor, i.e., the damping setting equals zero.
The following adjustments should be implemented.
The auxiliary servomotor opening is adjusted to 50% with the rated frequency. The load limiting device (abbreviated as 65P) should be set at the position where the converter input is zero.

b) The set stroke of the auxiliary servomotor should be measured with the rigid return scale as a parameter, changing $\pm \delta$ % of the rated frequency. The measured stroke of the auxiliary servomotor may be within 5 to 95 % of total stroke.
δ should be within 1/2 of the adjustment range of the specified speed droop.

6-2) Flexible return (damping)

a) Flexible return value:
The rigid return should be removed from the closing loop including the auxiliary servomotor. The time constant adjustment device of the flexible return should be locked, i.e., its capacitor should be shorted.
The output voltage of the flexible return should be measured in relation to the auxiliary servomotor stroke, with the flexible return scale as a parameter.

b) Time constant of flexible return:
A correct step input should be applied to the flexible return. The time when the output becomes 37 % of the peak value should be measured.

Note: An example of the test circuit is shown in the attached table.

7) Measurement schedule:

The following schedule is shown for reference.

8:00 Meeting before the measurement
Prepare for the measurement and lock the equipment shown in item 5)-c).
9:00 Add the input frequency and measure the servomotor stroke in relation to each rigid return scale.
Calculate the speed droop.
9:15 Next measurement is repeated. ……

8) Table for measurement:

Refer to the tables “Characteristic Test of Rigid and Flexible Returns for Governor (1), (2), (3)”

9) Judgment criteria:

a) Each characteristic test result should satisfy the specified value.

Characteristic Test of Rigid and Flexible Returns for Governor (1)

(I) Rigid return

Input frequency (Hz) / Setup scale of rigid return	Auxiliary servomotor stroke (mm)				
	2	4	6	8	10
Speed droop (%)					

Note:

a.) Setup scale of speed adjusting device (abbreviated as 65F) _____

b) Setup scale of load limiting device (abbreviated as 65P) _____

c) Calculation of speed droop

$D = \{(F_0 - F_{100}) / F_n\} * 100$ (%)

Where; D: Speed droop (%)

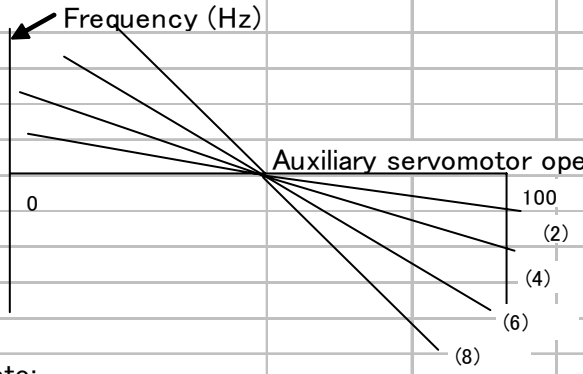
F_n: Rated frequency (Hz)

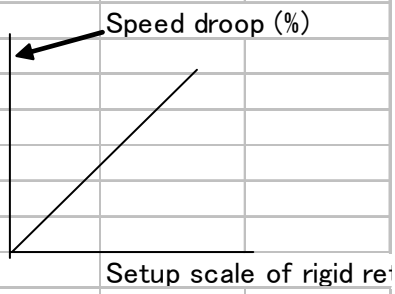
F_0: Frequency corresponding to 0 % of auxiliary servomotor opening

F_{100}: Frequency corresponding to 100 % of auxiliary servomotor ope

d) Specification Speed droop 0 to _____ %

e) Oil temperature _____ ℃





Note:

( ) indicates the setup target of rigid return

Characteristic Test of Rigid and Flexible Returns for Governor (2)

(2) Flexible return

	Voltage of flexible return (V)				
Setup scale of flexible return	2	4	6	8	10
Auxiliary servomotor stroke (mm)					
Temporary speed droop (%)					

Note:

a) Calculation of temporary speed droop

$D_{T=} V_R / V_D$

Where;

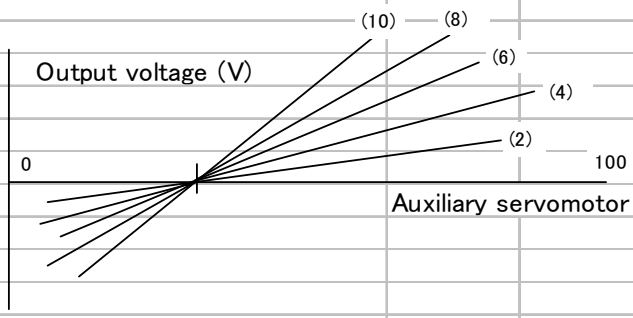
D_T: Temporary speed droop (%)

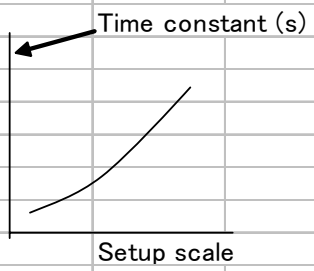
V_R: The voltage of flexible return per 100 % stroke of auxiliary servomotor (V)

V_D: Detected voltage per 1 % of frequency (V)

b) Specification temporary speed droop _____ %

e) Oil temperature _____ ℃





Note:

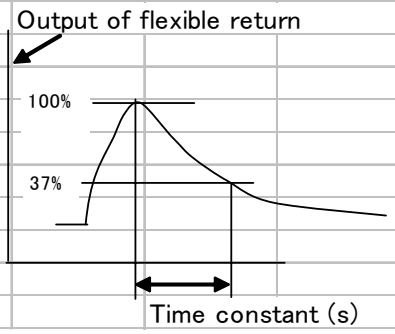
( ) indicates the setup target for time constant of flexible return

Setup target for time constant of flexible return

Setup target for time constant	Time constant (s)
1	
2	
3	
4	
5	

Note: Specification

Time constant of flexible return



(8) Characteristic Test of Speed Adjusting Device (abbreviated as 65F) and Load Limiting Device (abbreviated as 65P)

1) Purpose:

To confirm that the adjustment ranges satisfy the specifications, and each set value provides satisfactory linearity with respect to the speed adjusting device (65F) and load limiting device (65P).

2) Date: _____

3) Place: Unit _____ in _____ Hydropower Station

4) Assigned persons:

Measurement points	Communication	Name	Note
1. Commander			
2. Safety director			
3. Frequency			
4. 65F scale			
5. 65P scale			
6. Auxiliary servomotor opening			
7. Operator			

5) Measurement conditions:

a) This measurement is performed in the periodic inspection.
b) This measurement is a dry test.
c) Equipment to be locked for the test and other conditions are as follows:
- Equipment to be locked:
  No electrical lock
  Mechanical lock for inlet valve

6) Measurement procedure:

6-1) Characteristics of speed adjusting device (65F)

The following should be measured.

Input frequency, in which the output of the frequency detecting circuit becomes zero at each set value (position) of 65F
Operating time of control motor for 65F

6-2) Characteristics of load limiting device (65P)

The followings should be measured.

The auxiliary servomotor stroke at each set value (position)
Operating time of control motor for 65P

7) Measurement schedule:

The following schedule is shown for reference.

8:00 Meeting before the measurement
Prepare for the measurement and lock the equipment shown in item 5)-c).
9:00 Set up the 65F scale
Measure the frequency.
9:15 Next measurement is repeated. ……

8) Table for measurement:

Refer to the table “Characteristic Test of Speed Adjusting Device (65F) and Load Limiting Device (65P)”

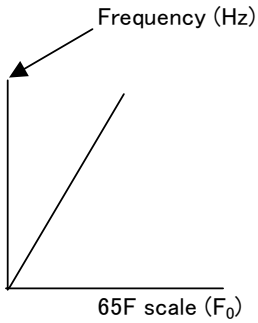
9) Judgment criteria:

a) Each characteristic test result should satisfy the specification.

Characteristic Test of Speed Adjusting Device (abbreviated as 65F) and Load Limiting Device (abbreviated as 65P)

(1) 65F

65F scale	Frequency (Hz)
0	
2	
4	
6	
8	
10	
Operating time of the control motor for 65F (65FM)	(s)



Note:

a) Specification:
Frequency adjusting range _____ Hz

b) Symbol of measurement terminal _____

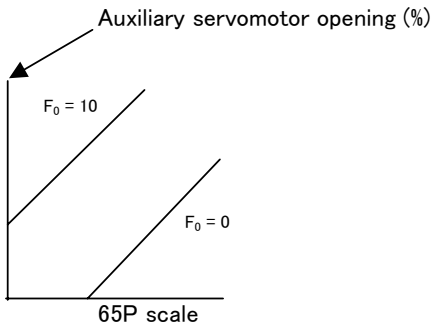
(2) 65P

Scale of 65P	Auxiliary servomotor opening (%)	
	F_0 = 0	F_0 = 10
0		
2		
4		
6		
8		
10		
Operating time of the control motor for 65P (65PM)	(s)	

Note:

a) Oil temperature _____ ℃

F_0: 65F scale



(9) Characteristic Test of Dead Band

1) Purpose:

To confirm that the dead band satisfies the specification.

2) Date: _____

3) Place: Unit _____ in _____ Hydropower Station

4) Assigned persons:

Measurement points	Communication	Name	Note
1. Control room as Commander			
2. Frequency			
3. Auxiliary servomotor movement			
4. Operator			

5) Measurement conditions:

a) This measurement is performed in the periodic inspection.
b) This measurement is a dry test.
c) Equipment to be locked for the test and other conditions are as follows:
- Equipment to be locked:
  No electrical lock
  Mechanical lock for inlet valve

6) Measurement procedure:

a) The auxiliary servomotor opening should be held at its middle position.
b) Input frequency for the frequency detecting circuit should be adjusted slightly up and down.
c) Then, the frequency at which the auxiliary servomotor starts should be measured.

Note: the following special measuring instrument is needed.

Precision frequency generator

/ Generated frequency: It should be possible to generate less than 0.01% of the rated frequency.
/ Generated voltage: It should be sufficient to supply the voltage to the frequency detecting circuit.

7) Measurement schedule:

The following schedule is shown for reference.

8:00 Meeting before the measurement
Prepare for the measurement and lock the equipment shown in item 5)-c).
9:00 Adjust the frequency slightly above and below the rated one.
Measure the frequency for the auxiliary servomotor to begin closing or opening movement.
9:15 Next measurement is repeated. ……

8) Table for measurement:

Refer to the table “Characteristic Test of Dead Band”

9) Judgment criteria:

a) The dead band should meet the specification.

Characteristic Test of Dead Band

Frequency for the auxiliary servomotor to begin closing movement (Hz)	
Frequency for the auxiliary servomotor to begin opening movement (Hz)	
Dead band (%)	

Note:

a) Calculation of dead band

$2\Delta = (Fc - F_0) * 100 / Fn$

Where;

2Δ: Dead band (%)

F_n : Rated frequency (Hz)

F_c : Frequency for the auxiliary servomotor to begin closing movement (Hz)

F_0 : Frequency for the auxiliary servomotor to begin opening movement (Hz)

b) Specification: Dead band _____ %

c) Oil temperature _____ ℃

(10) Indicial response test for governor

1) Purpose:

To confirm the dynamic characteristics of the speed control under no load operation

2) Date: _____

3) Place: Unit _____ in _____ Hydropower Station

4) Assigned persons:

Measurement points	Communication	Name	Note
1. Commander			
2. Safety director			
3. Setup scale of rigid return			
4. Setup scale of flexible return			
5. Setup target on time constant			
6. Step input			
7. Rotational speed			
8. Time			
9. Operator			

5) Measurement conditions:

a) This measurement is performed in the periodic inspection.
b) This measurement is a wet test.
c) Equipment to be locked for the test and other conditions are as follows:
- Equipment to be locked:
  No electrical lock
  No mechanical lock

6) Measurement procedure:

a) A step input corresponding to approximately ±5 % of the rated speed should be applied to the output terminal of the frequency detecting circuit under the governor's free operation with no load.
b) Under the above conditions, variations of rotational speed, auxiliary servomotor stroke, main servomotor stroke and step input should be recorded by an oscillograph.
c) Rigid and flexible returns should be adjusted to achieve the optimum dynamic characteristics.
d) No load damping should be comprehensively determined with the results of the governor dynamic characteristics and the load rejection.
e) Preparatory test with small input should be implemented to avoid excessive speed rise and hydraulic pressure.

7) Measurement schedule:

The following schedule is shown for reference.

8:00 Meeting before the measurement
Prepare for the measurement
9:00 Set up the oscillograph
Add the step input.
Confirm the rotational speed and the time until the defined stable condition.
9:15 Next measurement is repeated. ……

8) Table for measurement:

Refer to the table “Indicial Test for Governor”

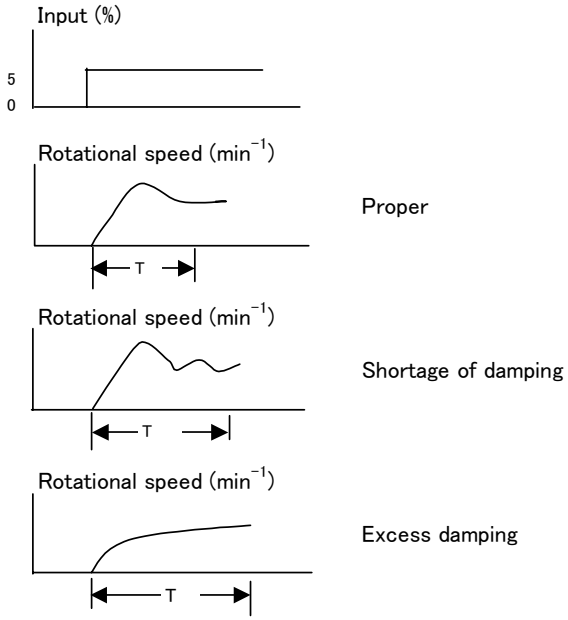
9) Judgment criteria:

a) The time required for the rotational speed to be stabilized should be as short as possible.

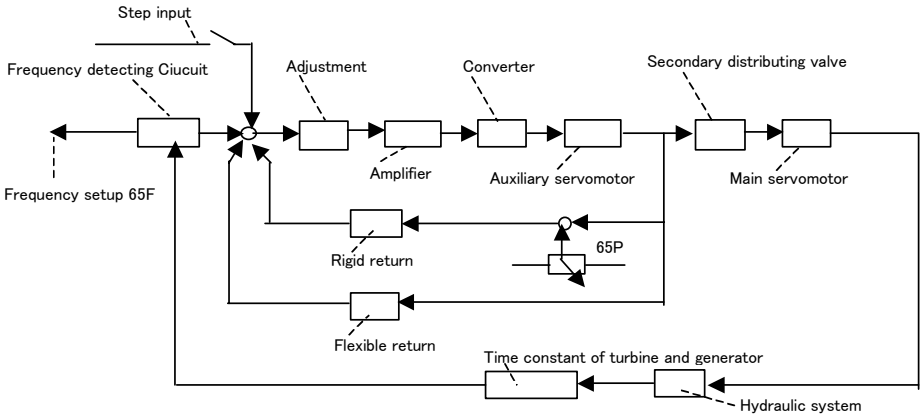
Indicial Response Test for Governor

Test number				Setup
Setup scale of rigid return				
Setup scale of flexible return				
Setup target on the time constant for flexible return				
Step input (%)				
Rotational speed (min^{-1})				
Before input				
Maximum (Minimum)				
After steadiness				
Time (s)				
Until maximum (minimum)				
Until steadiness				

Note: Oil temperature _____ ℃



Example of a test loop for indicial response



(11) Measurement of insulation resistance

1) Purpose:

a) To measure the insulation resistance of AC and DC circuits.
b) To confirm the secular change.

2) Date:

3) Place: Unit _____ in _____ Hydropower station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Commander			
2. Safety director			
3. Operator			
4. Staff No.1 who makes circuit to be measured			Refer to the note
5. Staff No.1 who makes circuit to be measured			Refer to the note

Note: The personnel who makes the circuit to be measured should make the circuit under observation of the safety director.

5) Measurement conditions

a) This measurement is performed in the periodic inspection
b) This measurement is a dry test
c) All grounding wires are removed from the circuit to be measured before the measurement. The circuit breakers that are connected to the circuit are locked. The circuit should be isolated from other circuits.
d) Operator should confirm there is no voltage on the circuit before the measurement.
e) Safety director should prohibit any person from entering the measurement area during the measurement.
f) The charged electricity on the circuit should be discharged after the measurement. Then the removed grounding wires should be reconnected immediately.

6) Measurement procedure

The main circuits to be measured are as follows:

- Between the PT (PD) circuit and earth
- Between the CT circuit and earth
- Between the DC circuit and earth
- Between the low voltage AC circuit and the DC circuit
- Between the stator coil and earth at the neutral grounding equipment
- Between the field coil and earth at the field circuit breaker
- Between each phase of the auxiliary circuit and earth

7) Measurement Schedule

8:00 Meeting before the measurement.
Prepare for the measurement
Safety director confirms the safety of the measurement area.
Operator confirms there is no voltage on circuit to be measured, and charges voltage.
9:00 Operator starts the measurement
9:01 Resistance value of 1 minute is measured.
9:02 Resistance value of 2 minutes is measured.
9:03 Resistance value of 3 minutes is measured.
9:04 Resistance value of 4 minutes is measured.
9:05 Resistance value of 5 minutes is measured.
9:06 Resistance value of 6 minutes is measured.
9:07 Resistance value of 7 minutes is measured.
9:08 Resistance value of 8 minutes is measured.
9:09 Resistance value of 9 minutes is measured.
9:10 Resistance value of 10 minutes is measured.
Operator discharges the electricity on the circuit.
Removed grounding wires are reconnected.
All locked equipment is unlocked.

8) Table for measurement:

Refer to the table “Measurement of insulation resistance”

9) Judgment criteria

Refer to the table “Measurement of insulation resistance”

Measurement of insulation resister

Weather:
Room temperature (^{o}C):
Outside temperature (^{o}C):

Time	At Start	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10min
MΩ											

Specification of measuring instrument: (500 V mega, 1000 V mega or 2000 V mega)

No. of Instrument	Name	Type	Rated	Manufacturing No.	Manufacturing Date	Manufacture

Judgment criteria (for reference)

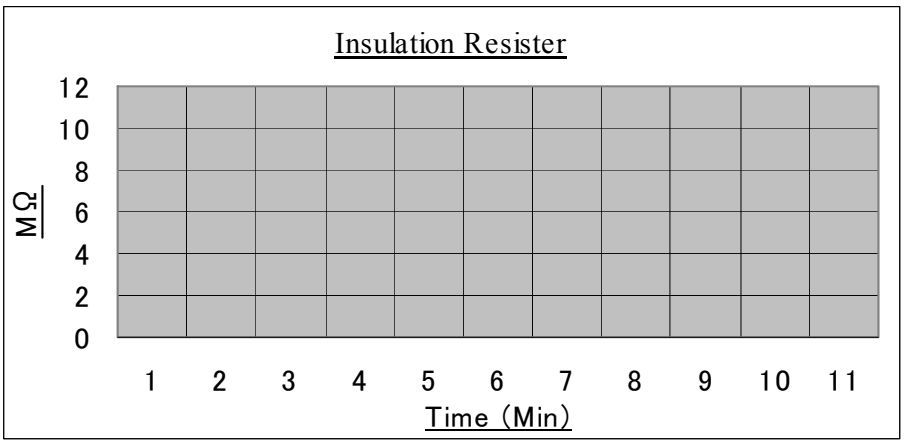
Calculation of Polarization Index (PI)

PI = Measurement value of 10 min / Measurement value of 1 min should be more than 1.5

Minimum Insulation Resister 1 for transformer (MIR)

More than 2 M Ohm for each circuit at humidity less than 90 % for AC low voltage
More than 75 M Ohm for coil between 6.6 kV and less than 22 kV at 40degree-C
More than 90 M Ohm for coil between 22 kV and less than 66 kV at 40degree-C
More than 100 M Ohm for coil of more than 66 kV at 40degree-C

Characteristic Curve of Insulation Resister



(12) Characteristic Test of voltage detecting circuit

1) Purpose:

To confirm the linearity and the gain to generator voltage of the output of the voltage detecting circuit.

2) Date: _____

3) Place: Unit _____ in _____ Hydropower Station

4) Assigned persons:

Measurement points	Communication	Name	Note
1. Commander			
2. Safety director			
3. Voltage			
4. Output			
5. Operator			

5) Measurement conditions:

a) This measurement is performed in the periodic inspection.
b) This measurement is a dry test.
c) Equipment to be locked for the test and other conditions are as follows:
- Equipment to be locked:
  Mechanical lock for the inlet valve, parallel-in circuit breaker and field circuit breaker
  Dummy generator voltage is supplied from the test terminal circuit.

6) Measurement procedure:

a) The rated generator voltage should be input into the voltage detecting circuit through a variable voltage supply set. The output of direct current to the voltage should be confirmed.
b) Every signal to various input voltages should be measured. The gain to detected voltage should be confirmed.
c) The detected voltage to the rated generator voltage should be determined.

7) Measurement schedule:

The following schedule is shown for reference.

8:00 Meeting before the measurement
Prepare for the measurement and lock the equipment shown in item 5)-c)
9:00 Operator operates the variable voltage generating set.
Measure the signal.
9:15 Next measurement is repeated. ……

8) Table for measurement:

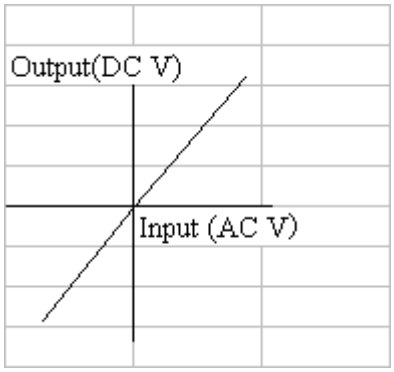
Refer to the table “Characteristic test of voltage detecting circuit in exciter system”

9) Judgment criteria:

a) The output of the voltage detecting circuit should have linearity and a satisfactory gain to generator voltage .

Characteristic test of voltage detecting circuit in exciter system

Input AC voltage (V)	Output DC voltage (V)



(13) Indicial response test for exciter

1) Purpose:

To confirm the dynamic characteristics of the voltage control under no load operation.

2) Date: _____

3) Place: Unit _____ in _____ Hydropower Station

4) Assigned persons:

Measurement points	Communication	Name	Note
1. Commander			
2. Safety director			
3. Oscillograph			
4. Generator voltage			
5. Field current			
6. Time			
7. Operator			

5) Measurement conditions:

a) This measurement is performed in the periodic inspection.
b) This measurement is a wet test.
c) Equipment to be locked for the test and other conditions are as follows:
- Equipment to be locked:
  No electrical lock
  No mechanical lock

6) Measurement procedure:

a) A step input corresponding to approximately ±10 % of the rated generator voltage should be applied to the output terminal of the voltage detecting circuit under normal operation with no load.
b) Under the above conditions, variations of generator voltage, field current, and step input should be recorded by an oscillograph.
c) Damping should be adjusted to achieve the optimum dynamic characteristics.
d) Damping should be comprehensively determined with the static characteristics of the voltage controller and the result of the load rejection.

7) Measurement schedule:

The following schedule is shown for reference.

8:00 Meeting before the measurement
Prepare for the measurement
9:00 Set up the oscillograph
Add the step input
Confirm the voltage and the time until the defined stable condition.
9:15 Next measurement is repeated. ……

8) Table for measurement:

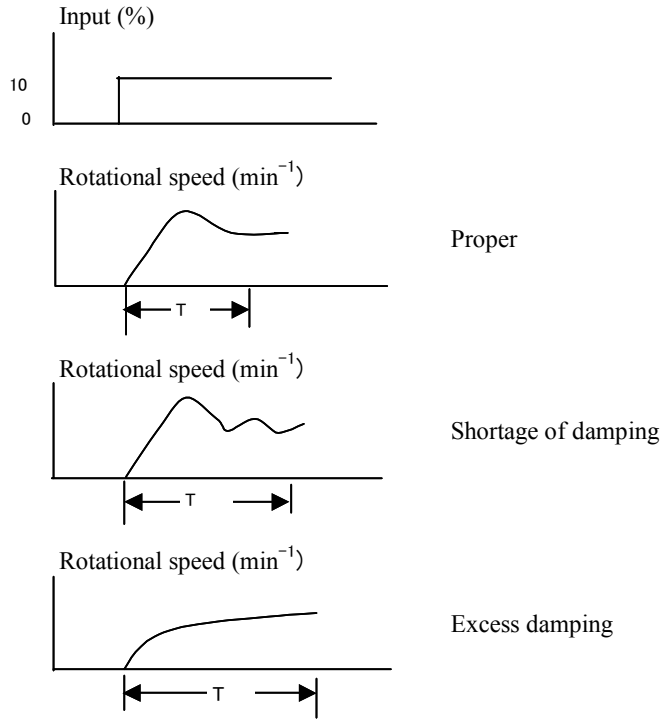
Refer to the table “Indicial Test for Exciter”

9) Judgment criteria:

a) The time required for the rotational speed to be stabilized should be as short as possible (J-POWER’s criterion: 2 Hz and below).

Indicial Response Test for Exciter

Test number				Setup
Step input (%)				
Generator voltage (V)				
Before input				
Maximum (Minimum)				
After steadiness				
Field current (A)				
Before input				
Maximum (Minimum)				
After steadiness				
Time (s)				
Until maximum (minimum)				
Until steadiness				
Field current (A)				
Set value of damping				



(14) Relay test (function test of thermal relay, level switch and pressure switch)

1) Purpose:

a) To ensure that the function of the thermal relay, level and pressure switch is correct.

2) Date:_____

3) Place: Unit____in_____Hydropower Station

4) Assigned persons:

Measurement point	Name	Note
1. Commander		
2. Safety director		
2. Relay checker		
3. Main operator for oil heater and dead weight gauge tester		
4. Sub-operator for oil heater and dead weight gauge tester		

5) Measurement conditions:

a) This measurement is performed in the periodic inspection
b) This measurement is a dry test
c) The relays to be measured should be removed from the turbine and generator. These relays should be inspected individually.
d) Equipment to be locked and other conditions are as follows:
- Equipment to be locked:
  No electrical lock
  No mechanical lock
- Other conditions:

The following items should be prepared before the measurement:

Standard thermometer
Oil basin
Oil heater
Dead weight gauge tester

6) Measurement procedure

a) Thermal relay
- The thermal relay probe and standard thermometer are placed into the basin filled with oil (or water).
- The oil (or water) temperature is raised up to the setting value by the oil heater (water heater).
- The actual temperature at the relay's opening and closing time is measured.

b) Level switch
- The level switch is placed into the basin filled with oil (or water).
- The actual range of the oil (or water) level at the relay's opening and closing time is measured

c) Pressure switch
- The pressure switch is placed into the dead weight gauge tester.
- The actual pressure value at the relay's closing and opening time is measured.

7) Measurement schedule

The following schedule is shown for reference.

8:00 Meeting before measurement
Preparation for measurement
10:00 Start of "Measurement"
- Measurement of thermal relay
- Measurement of level switch
- Measurement of pressure switch

8) Table for measurement

a) Thermal relay for alarm

Date: _____
Room Temperature: _____

Measurement point	Device No.	Setting value (°C)	Measured value (°C)
Alarm of turbine guide bearing			
Alarm of generator lower bearing			
Alarm of generator upper bearing			
Alarm of thrust bearing			

b) Thermal relay for shutdown

Date: _____
Room Temperature: _____

Measurement point	Device No.	Setting value (°C)	Measured value (°C)
Shutdown of turbine guide bearing			
Shutdown of generator lower bearing			
Shutdown of generator upper bearing			
Shutdown of thrust bearing			

c) Level switch

Date: _____

Room Temperature: _____

Measurement point	Device No.	Setting value (mm)		Measured value (mm)	
		Closing value	Opening value	Closing value	Opening value
Turbine guide bearing			-		-
Generator lower bearing			-		-
Thrust bearing			-		-
Oil tank					
Leakage oil tank					
Pressured oil tank					

d) Pressure switch

Date: _____

Room Temperature: _____

Measurement point	Device No.	Setting value (Pa)		Measured value (Pa)	
		Closing value	Opening value	Closing value	Opening value
Oil pressure in pressured oil tank					

9) Judgment criteria:

The measurement result should be judged by the criteria in the manufacturer's instructions.

(15) Burden check

1) Purpose:

a) To measure the burden of the circuit in control and protection relay boards.

2) Date: _____

3) Place: Unit _____ in _____ Hydropower Station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Commander			
2. Safety director			
3 Current meter			
4. Voltage meter			
5. Operator			
6. Staff member No. 1 who makes circuit to be measured			
7. Staff member No. 2 who makes circuit to be measured			

Note: The staff members who make the circuit to be measured should make the circuit under the observation of the safety director.

5) Measurement conditions:

a) This measurement is performed in the periodic inspection
b) This measurement is a dry test
c) The circuit to be measured should be isolated from other circuits.
d) The safety director should prohibit any person from entering the measurement area during the measurement.
e) Equipment to be locked and other conditions are as follows:
- Equipment to be locked:
  Electrical lock for the control, protection board and related equipment
  No mechanical lock
- Other conditions:
  An accurate power source should be prepared to supply the correct voltage and current to the circuit to be measured.

6) Measurement procedure

Current of the circuit is measured under rated voltage.

7) Measurement Schedule

Refer to the measurement schedule of "(5) Relay test"

8) Table for measurement:

Weather:
Room temperature (^{o}C):
Outside temperature (^{o}C):

Name of Circuit	Applied Voltage (V)	Applied Current (A)	Burden (VA)	Designed Burden (VA)

Specification of Measuring Instrument:

No. of Instrument	Name	Type	Rated	Manufacturing No.	Manufacturing Date	Manufacturer
	Test device for single-phase voltage and current					

9) Judgment criteria

There should be no significant difference between the measured values and the designed value.

(16) Overall sequence and operation test

1) Purpose:

a) To measure the sequence time of the start and stop of the generator with the turbine and auxiliary equipment.

2) Date: _____

3) Place: Unit _____ in _____ Hydropower station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Control room as commander			
2. Safety director			
2. Inlet valve			
3. Turbine pit			
4. Turbine control board			
5. Excitation board			
6. Surge tank			
7. Tailrace			
8. Operator			

5) Measurement conditions

a) This measurement is performed in the periodic inspection
b) This is a wet test.
c) The generator should be operated normally.
d) Equipment to be locked for the test and other conditions are as follows:
- Equipment to be locked:
  No electrical lock
  No mechanical lock
- Other conditions:
  None

6) Measurement procedure

a) Operator starts the generator normally.
b) Sequence time at each step during start sequence is measured.
b) Sequence time at each step during stop sequence is measured.

7) Measurement schedule

8:00 Meeting before the measurement
Prepare for the measurement
9:00 Operator starts the generator in normal procedure.
Start the measurement until the generator parallels in the system
9:20 The measurement from parallel-in to complete stop is performed.

8) Table for measurement

Weather:
Room temperature (^{o}C):
Outside temperature (^{o}C):

Operation Indicator on control board			Unit	Time	30S	Note
Start sequence (Time from start operation)	Inlet valve	Opening of bypass valve	min-s	-		
		Opening of main inlet valve	min-s	-		
	Start	Rated speed	min-s	-		
		Servomotor stroke at turbine start	mm			
		Closing of field circuit breaker	min-s	-		
	Parallel in	Operated automatic synchronize equipment	min-s	-		
		Parallel in from start control	min-s	-		
		Servomotor stroke at parallel in	mm	-		
		Penstock pressure at parallel in	mAq			
	Load	Achievement of load required	min-s	-		
		Generator output at the load	kW			
		Servomotor stroke at the load	mm			
Stopping sequence (Time from stop operation)	Stopping	Generator output before stop operation	kW			
		Servomotor stroke at before stop operation	mm	-		
		Parallel off	min-s	-		
		Brake start	min-s	-		
		Rotating speed at brake start	min^{-1}			
		Complete stop of generator	min-s	-		
	Inlet valve	Completion of main inlet valve closing	min-s	-		
		Completion of bypass valve closing	min-s	-		

Note: a) Water level of reservoir El._____ m, Water level of tailrace El._____ m,
b) Temperature of cooling water _____ ^{o}C
c) Temperature of oil sump tank _____ ^{o}C

9) Judgment criteria

a) To operate the generator without any delay or problem in each step in the sequence
b) There should be no significant difference between the measured values and the designed values.

2.2 Inspection manual of overhaul

(1) Output versus gate (or needle) opening test

1) Purpose:

a) To measure correlation between generator output and wicket gate opening (or needle opening).
b) To confirm the stable operation range and output restriction range as well as the looseness of the wicket gate (or needle) operating mechanism.
c) To check the difference between the measured value and the original setting value
d) To confirm the secular change

2) Date: _____

3) Place: Unit _____ in _____ Hydropower Station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Control room as Commander			
2. Safety director			
3. Generator output			
4. Generator voltage, current, power factor			
5. Field voltage, current			
6. Wicket gate (or needle, deflector) servomotor stroke			
7. Pressure			Refer to table
8. Vibration			Refer to table
9. Noise			Refer to table
10. Shaft run out			Refer to table
11. Water level			Refer to table
12. Pressure fluctuation			Refer to table
13. Operator			

5) Measurement conditions:

a) This measurement is performed during overhaul.
b) This measurement is a wet test.
c) The generator should be operated normally.
d) Equipment to be locked for the test and other conditions are as follows.
- Equipment to be locked:
  No electrical lock
  No mechanical lock
- Other conditions:
  None

6) Measurement procedure:

a) After the generator is paralleled, the generator is operated from no load to the maximum load.
b) The servomotor stroke is measured every 10% of the generator output. Similar measurements should be implemented in the closing direction.

c) The field voltage and field current should be measured. The rated power factor should be maintained.
d) The same procedure is applied to the stroke measurement from maximum output to no load.
e) The vibration, noise, shaft runout and pressure fluctuation should be measured to confirm the stable operation range.
f) The output restriction range should be determined in view of the net head, output and discharge.
g) Output should be measured by a precision class Wattmeter.
h) Pressure fluctuation should be measured with an oscillograph.
i) Operation direction (increasing or decreasing) of the output should not be changed during the measurement.
h) Each measurement should be performed after the output becomes stable.

7) Measurement schedule:

8:00 Meeting before the measurement
Prepare for the measurement
9:00 Operator starts the generator.
Set the generator output to 10% opening
Close the oil supply valve and set the servomotor stopper
Measure the wicket gate opening
9:15 Next measurement is repeated. ……

8) Table for measurement:

Refer to the table "Output versus gate opening test (Francis)"

9) Judgment criteria:

The proper correlation should be confirmed with respect to generator output and wicket gate (needle) servomotor stroke.

J-POWER's criteria of vibration and shaft runout are shown below as reference.

- Vibration in operation: 50 μ m P-P and below
- Shaft runout in operation: 70% and below of between shaft and bearing metal
- Shaft runout in assembly: 50 μ m P-P and below (for domestic power station)
  L/D * 0.05mm (for foreign power station)
  L: distance of shaft direction from sliding surface of thrust bearing to measuring point
  D: diameter of thrust bearing metal

Output versus gate opening test (Francis)

Weather:

Room temperature:

Outside temperature:

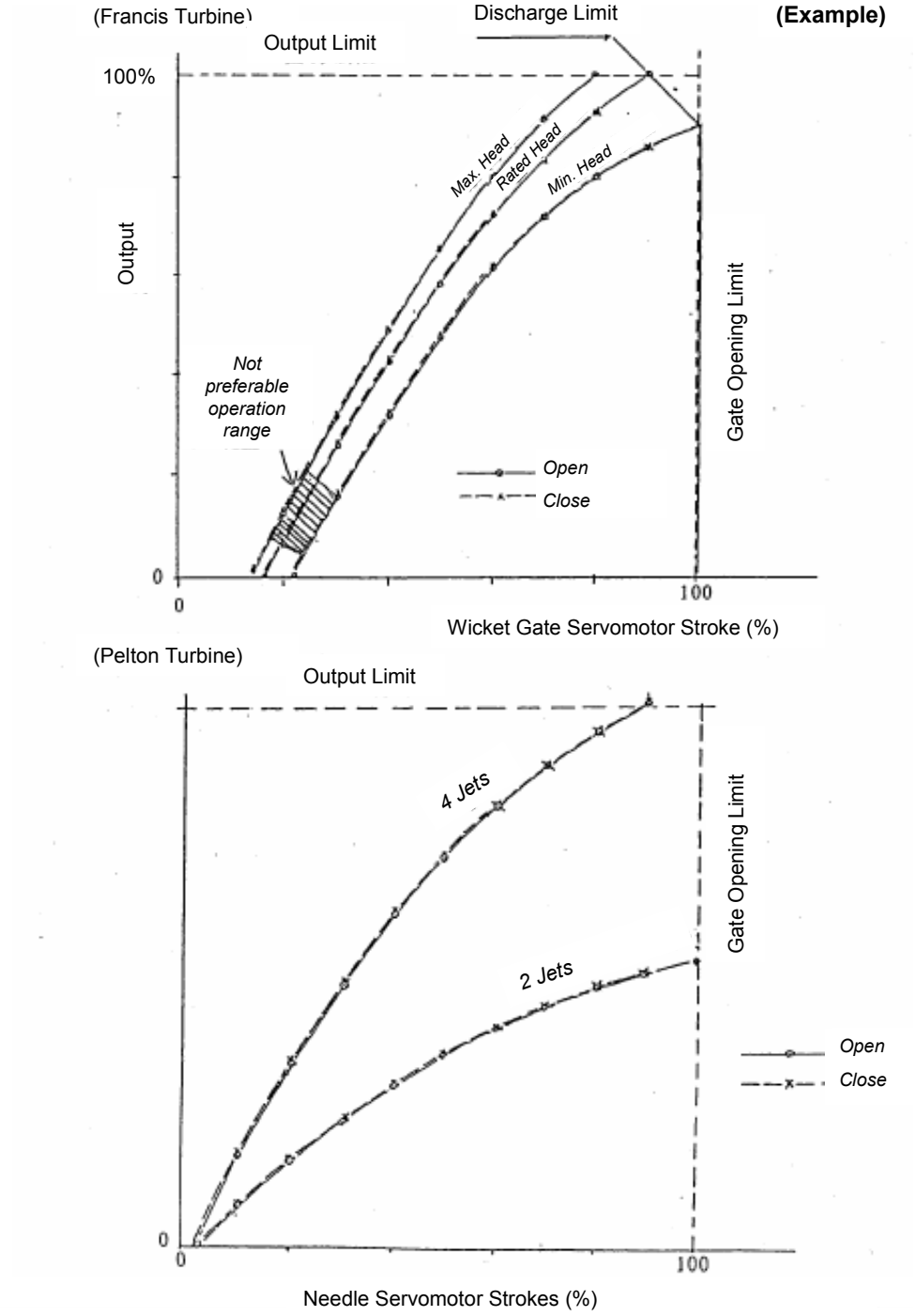
Measurement number											
Generator:											
	Output (kW)										
	Voltage (V)										
	Current (A)										
	Power factor (%)										
	Field voltage (V)										
	Field current (A)										
Gate opening											
	Wicket gate servomotor stroke (%)										
	Wicket gate servomotor stroke (mm)										
Pressure:											
	Penstock (mAq)										
	Spiral case (mAq)										
	Runner back (mAq)										
	Runner side (mAq)										
	Draft tube (mAq)										
Air supply valve opening:											
	Draft tube (%)										
Vibration:											
	Upper bearing:										
	Vertical (μ)										
	Horizontal (μ)										
	Tangential (μ)										
	Circumferential										
	Lower bearing:										
	Vertical (μ)										
	Horizontal (μ)										
	Tangential (μ)										
	Circumferential										
	Turbine bearing:										
	Vertical (μ)										
	Horizontal (μ)										
	Tangential (μ)										
	Circumferential										
Shaft runout											
	Generator:										
	Upper shaft (1/100 mm)										
	Lower shaft (1/100 mm)										
	Turbine shaft (1/100 mm)										
Noise:											
	Measurement range (A or C)										
	Turbine pit (dB)										
	Draft tube manhole (dB)										
Pressure											
	Spiral case (mAq)										
	Draft tube (mAq)										
Water level:											
	Upper reservoir (EL)										
	Surge chamber (EL)										
	Tailrace (EL)										
	Lower reservoir (EL)										

Note:

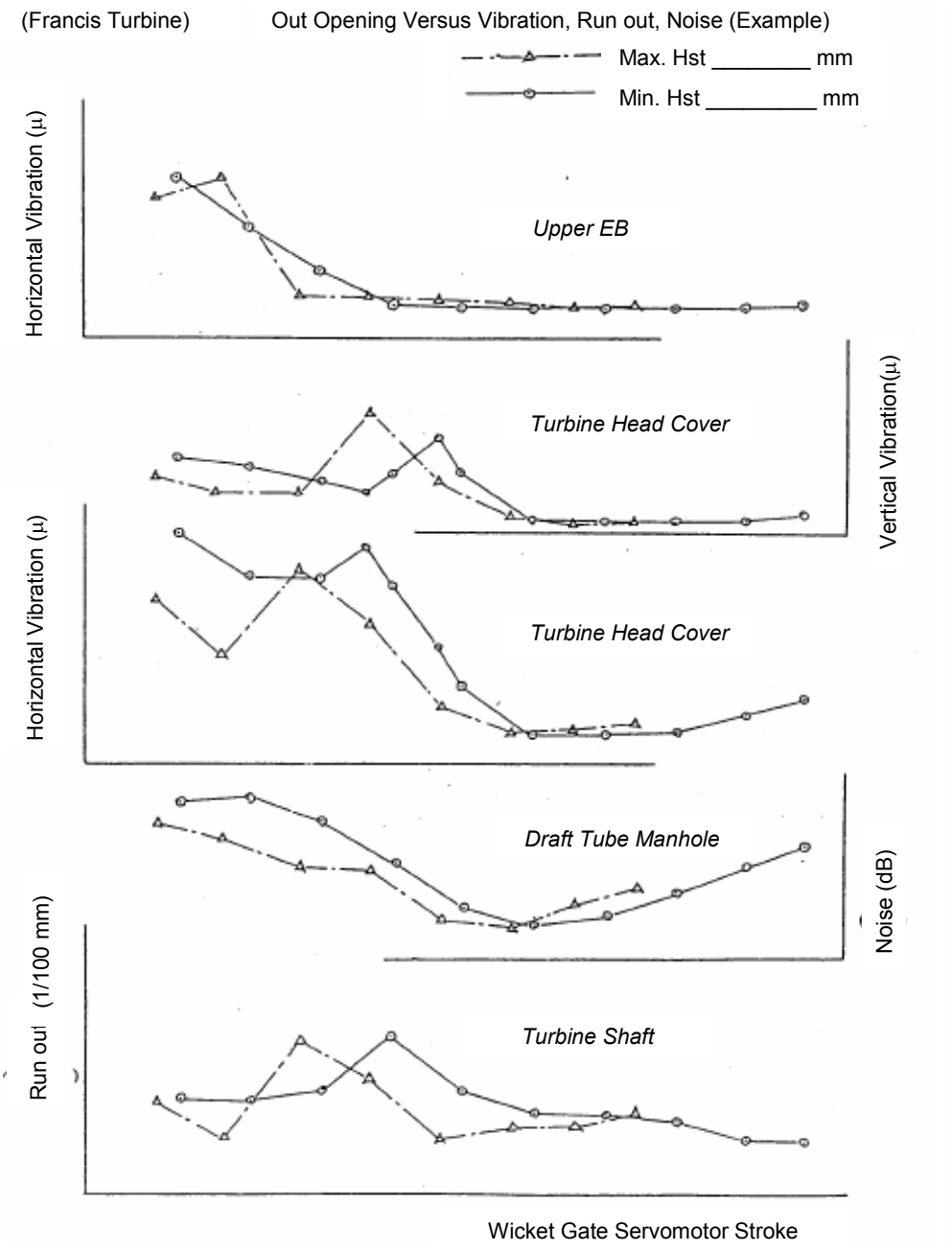
a. Maximum servomotor stroke _____ mm

b. Sump tank temperature _____ deg. Celsius

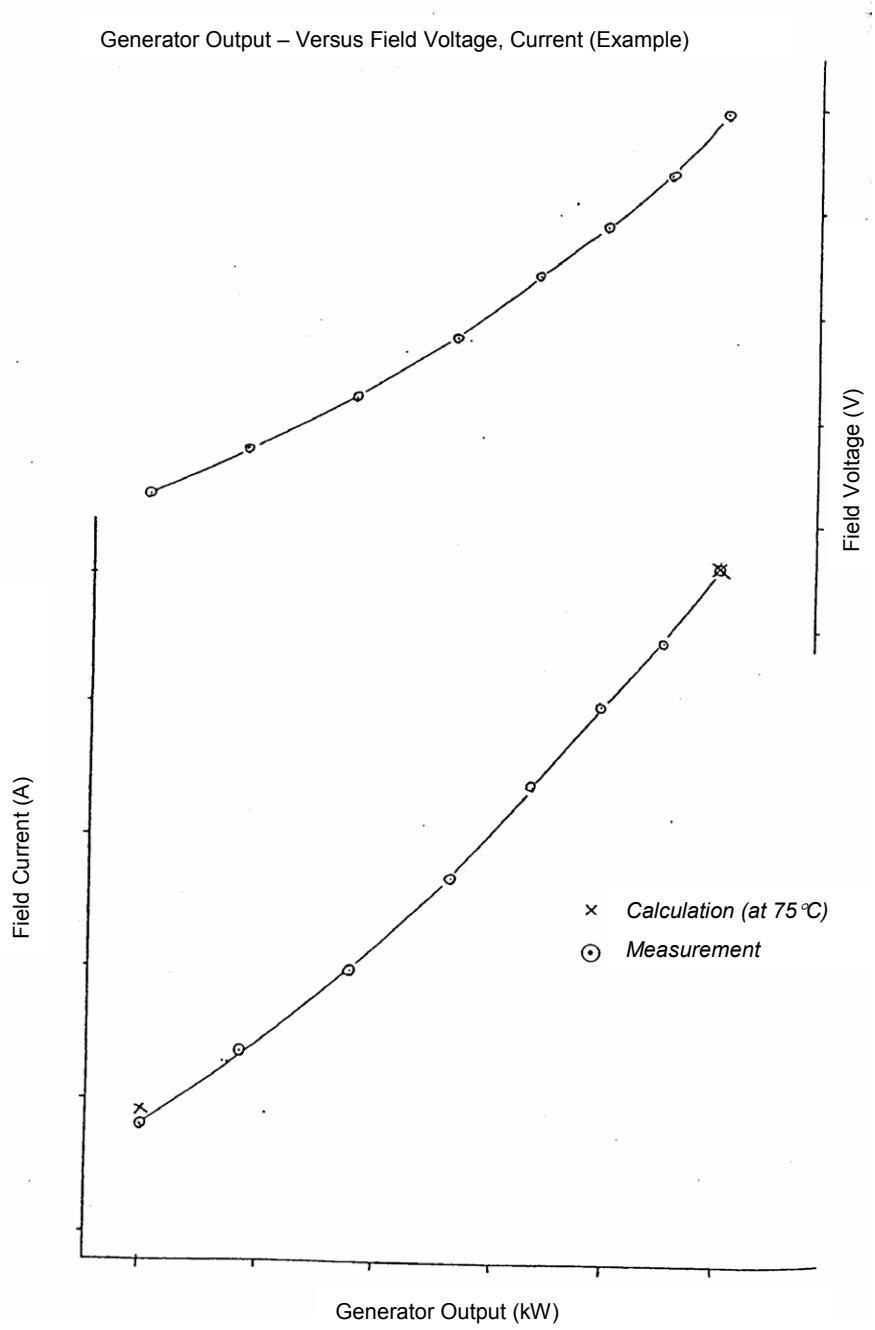
Output Versus Gate Opening Test



Output Versus Gate Opening Test



Output Versus Gate Opening Test



(2) Load rejection test

1) Purpose:

a) To ensure that the generator can be stopped safely at load rejection.
b) To confirm that the rotating speed and the penstock pressure do not exceed the guaranteed value.

2) Date: _____

3) Place: Unit _____ in _____ Hydropower Station

4) Assigned persons:

	Measurement point	Communication	Name	Note
1	Commander			
2.	Safety director			
3.	Watt meter VAR meter			Generator active power Generator reactive power
4.	Volt meter			Generator voltage
5.	Current meter			Generator current
6.	Volt meter Current meter			Field voltage Field current
7.	Tachometer			Rotating Speed
8.	Scale			Servomotor stroke
	Stop watch			Closing time of servomotor
9.	Oil press. tank			Oil pressure and oil level
10.	Pressure meters			Water pressure of penstock Water pressure of draft tube Water pressure of runner-back/side Water pressure of spiral case
11.	Water level detector gauge			Maximum and minimum of water level in surge tank
12.	Dial indicator Gap sensor			Shaft runout of upper and lower shaft Shaft runout of turbine shaft
13.	Vibration sensor			Vibration of upper and lower bracket Vibration of turbine head cover
14.	Dial indicator			Deflection of lower bracket
15.	Generator and			Ambient temperature in generator room
16.	Operator			

5) Measurement conditions:

a) This measurement is performed during overhaul.
b) This measurement is a wet test.
c) The generator should be operated normally.

d) Equipment to be locked for the test and other conditions are as follows:
   - Equipment to be locked:
     No electrical lock
     No mechanical lock
   - Other conditions:
     None

6) Measurement procedure

a) The heads to be tested will be available as high heads. Loads to be tested are 1/4, 2/4, 3/4 and 4/4 of the rated loads.
b) The test start at 1/4 load.
c) The generator is operated at the rated speed, voltage and power factor.
d) The water level in the surge tank should be stable.
e) The transient status of wicket gate, pressure in the penstock and draft tube, rotating speed and generated voltage, current, active power, reactive power, field voltage and field current should be recorded by the oscillograph.
f) After the above conditions are completed, the test should be started.
g) If any conditions are changed, such as adjustment of closing time of the wicket gate, the same test should be performed after finishing the proper adjustment.

7) Measurement schedule

The following schedule is shown for reference.

8:00 Meeting before the measurement
     Prepare for the measurement
8:50 Operator starts the generator
8:55 Call "Five minute before" from commander and ring the bell
9:00 Call "3-2-1-Measurement" from commander and ring the bell
     Measure each item
     Reporting from points to recording person

8) Table for measurement

Refer to the table "Load rejection test"
The table is based on the measurements for the Francis turbine. These measurements should be changed according to actual condition of the turbine to be measured.

9) Judgment criteria

a) The measurement results should be judged based on the values guaranteed in the contract.

Guaranteed values
- Variation ratio of voltage (delta-V): below____% (at p.f.__%)
- Variation ratio of rotating speed (delta-v): below____%
- Maximum water pressure (Pmax): below____m
- Dead time of governor closing: below___sec

b) To confirm there is no abnormality due to load rejection

Load rejection test

					%	1/4	2/4	3/4	4/4	-
Load					%					
Time					h-m					
System voltage		At load			kV					
		After rejection			kV					
Generator	Output				MW					
	Voltage	At load			kV					
		Maximum								
		Stabilized								
		Variation ratio			%					
	Current				kA					
	Reactive power				MVAR					
	Frequency				Hz					
	Ex.		Voltage		V					
			Current		A					
Turbine	Main servomotor	Stroke	At load		mm					
			Stabilized							
		Closing	T_1		sec.					
			T_2							
	Speed	At load			min^{-1}					
		Maximum								
		Stabilized								
		Variation ratio			%					
	Penstock Pressure	At load			m					
		Maximum								
		Stabilized								
		Variation								
		Static head								
Turbine	Spiral case pressure		At load		m					
			Maximum							
			Stabilized							
	Runner back pressure (Outer)		At load		m					
			Maximum							
			Stabilized							
	Runner side pressure		At load		m					
			Maximum							
			Stabilized							
	Draft tube pressure		At load		m					
			Maximum							
			Minimum							
			Stabilized							
	Pressure oil tank	Oil press	At load		MPa					
			Minimum							
		Oil level	At load		mm					
			Minimum							
Water level	Upper reservoir EL				m					
	Lower reservoir EL									
	Static head just before load rejection (URWL-LRWL)				m					
	Surge tank		At load		m					
			Maximum							
			Minimum							
			Stabilized							
Oil temperature					°C					
Room temp. G/M, P/T										

Penstock pressure variation = Max. pressure - static head at load

Static head at load = Upper reservoir W.L just before load rejection – turbine center

Wicket gate servomotor stroke _____mm

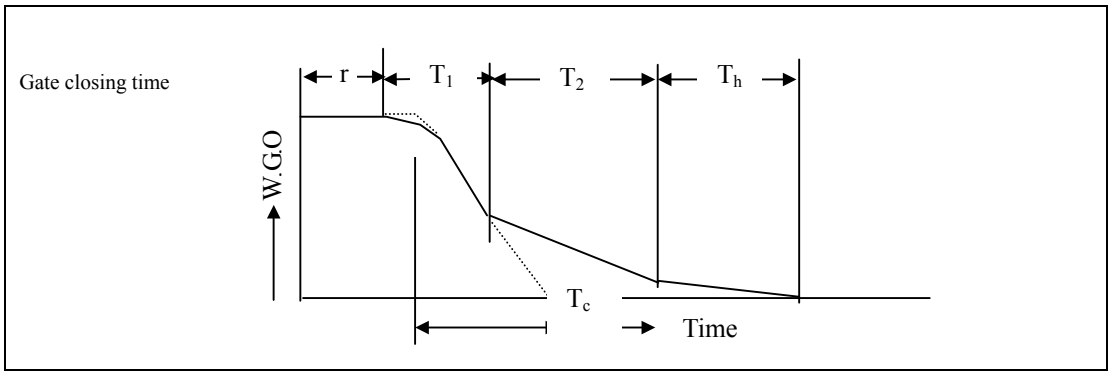
Turbine center EL _____m

Voltage variation ratio = $\frac{\text{Max. voltage - At loading voltage}}{\text{Rated voltage}}$

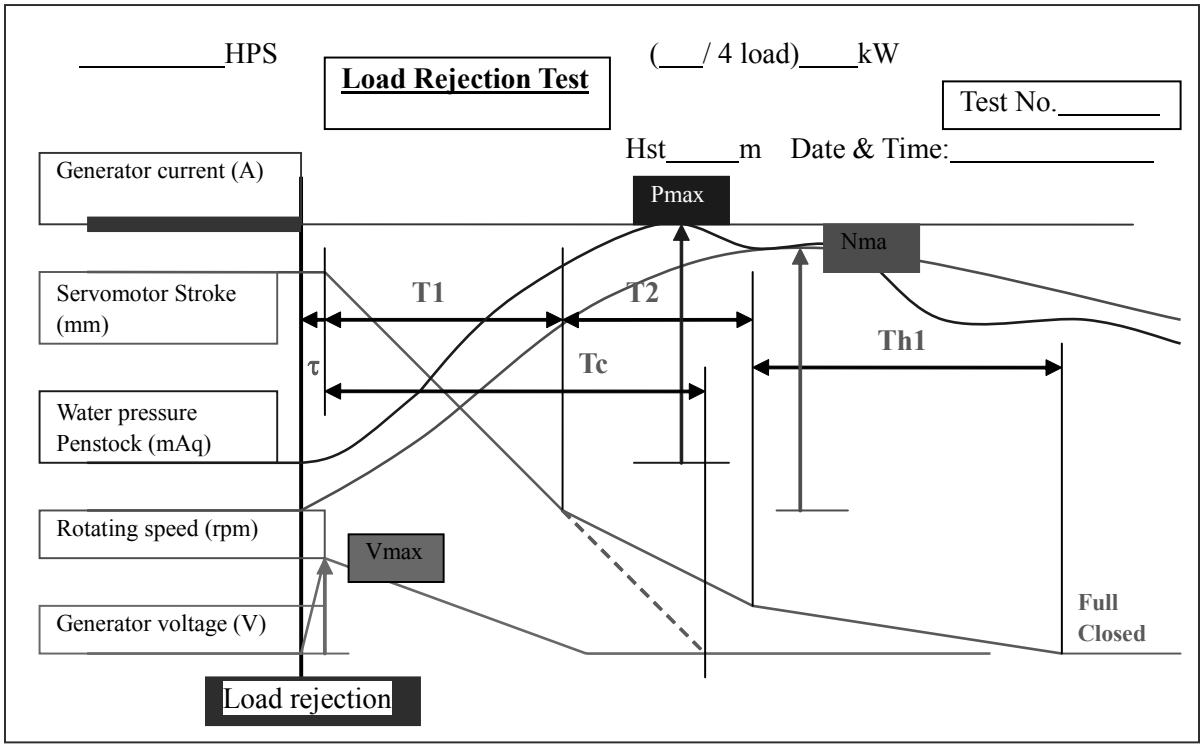
Gauge center EL _____m

(Gauge height: _____m)

Speed variation = $\frac{\text{Max. speed- At loading speed}}{\text{Rated speed}}$ t



(**Sample Data of Oscillograph**)



(3) Load test

1) Purpose:

a) To ensure that the generator can be operated without any trouble under full load operation.

2) Date: _____

3) Place: Unit___ in _____Hydropower Station

4) Assigned persons:

	Measurement point	Communication	Name	Measurement
1.	Commander			
2.	Safety director			
2.	Instruments Wattmeter VAR meter Voltmeter Ammeter Voltmeter			System voltage Generator active power Generator reactive power Generator voltage Generator current Generator frequency Generator watt hour Field Voltage, Field Current
3.	Turbine pit 1			Wicket gate stroke
4.	Water pressure meters			Water pressure of penstock Water pressure of spiral case Water pressure of runner back Water pressure of runner side Water pressure of draft tube
5.	Generator room 1			Shaft run-out of generator upper shaft
6.	Turbine pit 2			Shaft run-out of generator lower shaft Shaft run-out of turbine shaft
7.	Pressure oil tank			Oil pressure of pressure oil tank
8.	Oil Tank			Oil temperature of oil tank
9.	Resistance type thermometers 1			Coil temperature of generator stator (Red, Yellow and blue phase) Oil temperature of generator thrust bearing Oil temperature of generator upper guide bearing Oil temperature of generator lower guide bearing
10.	Resistance type thermometers 2			Oil temperature of turbine guide bearing Water temperature at air cooler inlet Air temperature at air cooler inlet Air temperature at air cooler outlet
12.	Transformer			Oil temperature at generator transformer
13.	Dial type thermometers			Water temperature at air cooler inlet Water temperature at thrust bearing outlet Water temperature at generator lower guide bearing outlet Water temperature at turbine guide bearing outlet

	Measurement point	Communication	Name	Measurement
14.	Generator, turbine and transformer room			Ambient temperature in generator room Ambient temperature in turbine room Ambient temperature in generator transformer room
15.	Outside of power house			Ambient temperature outside of powerhouse
16.	Upper reservoir			Water level upper reservoir
17.	Lower reservoir			Water level lower reservoir
18.	Operator			
19.	Bell and recording person			

5) Measurement conditions:

a) This measurement is performed during overhaul.
b) This measurement is a wet test.
c) The generator should be operated normally.
d) Equipment to be locked for the test and other conditions are as follows.
   - Equipment to be locked:
     No electrical lock
     No mechanical lock
   - Other conditions:
     None

6) Measurement procedure

a) Operator keeps the generator to the rated speed, voltage, output and power factor.
b) Interval of these measurements is every 10 minutes in the first hour and every 30 minutes after one hour.
c) Assigned persons should take care of abnormal vibration, shaft run-out, oil leakage, water leakage and abnormal sound of the main unit, and any abnormality of the auxiliary machines observed during the load test.
d) Test should be continued until each temperature is saturated.

7) Measurement schedule

The following schedule is shown for reference.

8:00 Meeting before the measurement
Move to measurement points
8:50 Operator start the generator
8:55 Call "Five minute before" from commander and bell ring
9:00 Call "3-2-1-Measurement" from commander and bell ring
Measure the each item
Reporting from points to recording person
9:10 Call "3-2-1-Measurement" from commander and ring the bell
Measure each item
Reporting from points to recording person ……

8) Table for load measurement

Refer to the table “Load test”
The table is based on the measurements for the Francis turbine. These measurements should be changed according to the actual condition of the turbine to be measured.

9) Judgment criteria

a) The measurement results should be judged based on the value guaranteed in the contract.

Guaranteed value (for reference)
- Maximum temperature of bearing (°C): below 65 °C
- Temperature rise of stator coil: below 80 K (at ambient temperature below 40 °C)
- Temperature rise of rotor coil: below 80 K (at ambient temperature below 40 °C)

Load test

	Measurement item	Instrument	Location	9:00	9:10	9:20	9:30	9:40	9:50	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30
1.	System voltage	Voltmeter															
2.	Generator active power	Wattmeter															
3.	Generator reactive power	Varmeter															
4.	Generator voltage	Voltmeter															
5.	Generator current	Ammeter															
6.	Generator frequency	Hz meter															
7.	Generator watt hour	Watt hour															
8.	Field Voltage	Volt meter															
9.	Field Current	Am meter															
10.	Wicket gate stroke	W.G scale															
11.	Water pressure of penstock	Pressure gauge															
12.	Water pressure of spiral case	Pressure gauge															
13.	Water pressure of runner back	Pressure gauge															
14.	Water pressure of runner side	Pressure gauge															
15.	Water pressure of draft tube	Pressure gauge															
16.	Shaft run-out of generator upper shaft	Dial indicator															
17.	Shaft run-out of generator lower shaft	Dial indicator															
18.	Shaft run-out of turbine shaft	Dial indicator															
19	Oil pressure of pressure oil tank	Oil level gauge															
20	Oil temperature of oil tank	Bar type thermometer															
21.	Coil temperature of generator stator (Red, Yellow and blue phase)	Resistance type thermometer															
22.	Oil temperature of generator thrust bearing	Dial thermometer and Resistance type thermometer															
23.	Oil temperature of generator upper guide bearing	Dial thermometer and Resistance type thermometer															
24.	Oil temperature of generator lower guide bearing	Dial thermometer and Resistance type thermometer															
25.	Oil temperature of turbine guide bearing	Dial thermometer and Resistance type thermometer															
26.	Water temperature at air cooler inlet	Resistance type thermometer															
27.	Air temperature at air cooler inlet	Resistance type thermometer															
28.	Air temperature at air cooler outlet	Resistance type thermometer															
29.	Oil temperature at generator transformer	Dial thermometer															
30.	Water temperature at air cooler inlet	Dial thermometer															
31.	Water temperature at thrust bearing outlet	Dial thermometer															
32.	Water temperature at generator lower guide bearing outlet	Dial thermometer															
33.	Water temperature at turbine guide bearing outlet	Dial thermometer															
34.	Ambient temperature in generator room	Bar type thermometer															
35.	Ambient temperature in turbine room	Bar type thermometer															
36.	Ambient temperature in generator transformer room	Sound meter															
37.	Ambient temperature of outside of powerhouse	Bar type thermometer															
38.	Water level upper reservoir																
39.	Water level lower reservoir																

(4) Simplified efficiency test

1) Purpose:

a) To measure turbine efficiency with a portable flow meter.

2) Date: _____

3) Place: Unit____in_____Hydropower Station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Control room as Commander	WT 1		
2. Safety director			
3. Penstock	WT 2		One assistant is need.
4. Headrace	Tel		
5. Tailrace	WT 3		
6. Servomotor stroke	4		
7. Cubicle room	WT4		
8. Penstock pressure	4		
9. Surge chamber	Tel		
10. Turbine operator	1		

Notice: WT is the walkie-talkie's number. The person who has just a number in the column in the table should communicate the measurement value to the person who has the same WT number .

5) Measurement conditions:

a) This measurement is performed during overhaul.
b) This measurement is a wet test.
c) The efficiency of the turbine should be measured under normal operation.
d) Equipment to be locked and other conditions are as follows:
- Equipment to be locked:
  No electrical lock
  No mechanical lock
- Other conditions:
  The other turbines should be stopped (or operated at constant output).

6) Measurement procedure

a) Operator starts the turbine by normal procedure.
b) Turbine output should be kept constant during the measurement.
c) Each measurementshould be performed after 5minute or more from output change.
d) It is better to perform a trial measurement before the actual measurement.

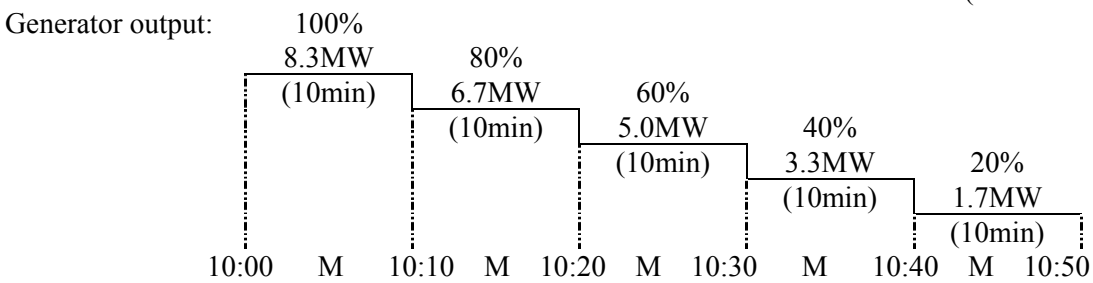
7) Measurement schedule

The following schedule is shown for reference.

8:00 Meeting before measurement
Move to measurement points
8:50 Confirmation of assigned person at every point from control room
8:59 Call "One minute before" from commander (Trial)
9:00 Call "3-2-1-Measurement" from commander (Trial)
Measure the each item (Trial)
Reporting from points to recording person (Trial)
9:55 Reconfirmation of assigned person at every point
10:04 Call "One minute before" (Actual)
10:05 Call "3-2-1-Measurement" (Actual)
Measure each item (Actual)
Reporting from points to recording person (Actual)

The following figure shows the output schedule of the simplified efficiency test for unit 1 in the Laxapana hydropower station.

(For reference)



8) Table for measurement

Refer to table "Simplified efficiency test"

9) Judgment criteria

a) The measurement results should be judged based on the value guaranteed in the contract in consideration of secular change.

Simplified efficiency test

PS Name: Survey date:

Unit Number: Weather:

Flow coefficient: Room temperature: degree Celsius

Outside temperature: degree Celsius

Measurement point		Unit	Practice	10:05	10:15	10:25	10:35	10:45	Remarks
Generator	Generator output	MW							Control room
	Generator reactive power	MVar							Control room
	Time of 100kWh or 200kWh	min sec							Cubicle room, Blue letter 100kWh
	Calculated G. output	MW							
	Generator voltage	kV							Control room
	Generator current	A							Control room
	Field winding voltage	V							Control room
	Field winding current	A							Control room
	Power factor (p.f.)	%							
	Frequency	Hz	-	-	-	-	-	-	Control room
	Coil temperature	°C	-	-	-	-	-	-	
Turbine	Rotational speed	mim^{-1}							Control room
	Wicket gate opening	mm	-	-	-	-	-	-	
	Needle opening #1	mm							Servomotor stroke (0MW, 31mm)
	Needle opening #2	mm							Servomotor stroke (0MW, 34mm)
	Needle opening #3	mm	-	-	-	-	-	-	
	Needle opening #4	mm	-	-	-	-	-	-	
	Deflector Opening	%							Servomotor stroke
Discharge	Used flow (discharge)	m^3/s							Penstock A
Head	Water level of Intake	ft inch							Headrace
	Water level of surge chamber	m							Surge Chamber
	Water level of tailrace (weir)	m							Tailrace
	Penstock pressure gauge (in)	ft							Penstock pressure
	Penstock pressure gauge (out)	ft							Penstock pressure

Measurement point		Unit	Practice	10:05	10:15	10:25	10:35	10:45	Remark
Calculated Head	Water level of intake	EL..m							
	Water level of surge chamber	EL..m							
	Turbine center	EL..m							
	Pipe loss	m							
	Pressure head	m							
	Goss head	m							
	Effective head	m							
Gene. Loss	Iron loss	kW							
	Mechanical loss	kW							
	Resistance of stator winding	Ω							
	Resistance loss	kW							
	Floating load loss	kW							
	Field loss	kW							
	Total generator loss	kW							
Efficiency	Generator efficiency	%							
	Turbine output	MW							
	Turbine input	MW							
	Turbine efficiency	%							
	G-T efficiency	%							
Converted value to the	Effective head	m							
specification	Discharge	m^3/s							
	Turbine output	kW							