Noval Method of Performance Testing of Generator

Generator Dynamic Testing

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Abstract— Generator is the most important and costly equipment in the complete power system setup. For the reliability of power system, protection of generator is essential. To verify the overall protection system of the generator by actually creating fault conditions and then observing the operation of relays is known as Dynamic testing of generator. This paper proposes an insight to the generator dynamic testing. The proposed testing was conducted at Mahagenco CSTPS Chandrapur 500MW unit. In the dynamic testing Short circuit characteristic (SCC), Open circuit characteristic (OCC), of generator are achieved by actually running the generator with the help of prime mover at rated speed and then performing tests by open circuiting and shorting at the transmission side isolators. The healthiness of all the CT/PT and its associated circuits was also confirmed. Healthiness and operation stability of generator back up impedance protection, generator differential protection/ Over all differential protection under actual fault conditions, generator earth fault protection under actual fault conditions, generator differential protection/ Over all differential protection while supplying through currents, is ensured via actual operation of Negative phase sequence protection and operation and stability of restricted earth fault protection. The characteristics achieved by dynamic testing are then compared with the actual design characteristics of the generator. The paper gives a detail procedure and test results of the said test conducted for measuring dynamic performance of generator.

Keywords- *Generator, Dynamic Testing, Operation stability , Short circuit characteristic (SCC), Open circuit characteristic (OCC)*

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I. INTRODUCTION

Generator is the most important and costly equipment in the complete power system setup. For the reliability of power system, protection of generator is essential. The generator protection can be achieved through different fault prevention methods. These methods can be briefly classified for generator protection under operational methods [7]-[8]

1. Protections against Electrical Faults
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A. Unit Protection (against Internal faults)
- Differential Protection
- Stator Earth Fault Protection
- Rotor Earth Fault protection
- Inter-turn Fault Protection.

B. Non-unit Protection (against Uncleared External Faults)
- Voltage Controlled / Restraint O/C Relays.
- Impedance Backup Protection.

2. Protections against Abnormal Operating Conditions

- Unbalanced Load Protection (NPS Current Relay)
- Field Failure Protection
- Anti-motoring Protection
- Over Excitation Protection (for G.Ts.)
- Under / Over Frequency Protection
- Over Voltage Protection
- Over Load Protection

Generator in a power station requires different types of protections. These protections are provided by various types of relays which may be electromagnetic or static. In case of numerical relays, most of the electrical protections can be taken care of by a single relay. Modern, microprocessor-based generator protection relays integrate many functions into a single package.[1]-[8]-[9] Each protection element is designed to detect a specific abnormal condition in the system and to initiate a particular tripping sequence. Static testing of individual functions in many cases will not validate the ability of the entire package to respond correctly to different system conditions. This is particularly true for generator protection.[7]-[8]

Simulation of the said generator protections in real environment and fault analysis of the same will be carried out for the same.[5] To check the overall protection system of the generator by actually creating fault conditions and then observing the operation of relays is known as Dynamic Testing of generator. The said dynamic testing is carried out by following a specific step by step procedure.[6]

The said dynamic testing is performed at Mahagenco CSTPS Chandrapur. 500MW 2pole Turbo-Generator with primary water and hydrogen cooling. THDF type of Generator with directly water cooled stator winding and hydrogen cooling for stator core and rotor. The parameters of generator are 500MW 588MVA 0.85Lag 21KV 16200A. The Hydrogen Pressure of the Generator being 4kg/cm2 and its insulation class is micalastic (High Voltage Insulation)

Brushless Excitation System is provided which consists of a 3phase permanent magnet pilot exciter the output of which is rectified and controlled by Thyirstor Voltage Regulator to provide a variable DC current for the main exciter. The 3phase are induced in the main exciter and then rectified by the

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rotating diodes to the field winding of the rotor of the main generator by dc leads fed in the rotor shaft. Since the rotating rectifier is mounted on the rotor the slip rings are not required and the output of the rectifier is directly connected to the filed winding of the generator through the rotor shaft. A common shaft carries the rectifier wheel the rotor of the main exciter and the permanent magnet generator.

II. PURPOSE OF DYNAMIC TESTING

To ensure the healthiness and operation stability of

- Generator back up impedance protection under actual fault conditions.
- Generator differential protection/ Over all differential protection under actual fault conditions.
- Generator earth fault protection under actual fault conditions.
- Generator differential protection/ Over all differential protection while supplying through currents.
- To ensure actual operation of Negative phase sequence protection.
- To ensure actual operation and stability of restricted earth fault protection.
- To obtain reference data regarding behavior of excitation system.

Followings things that are achieved by dynamic testing are

- Short circuit characteristic of the generator (SCC)
- Open circuit characteristic of the generator (OCC)
- To ensure the healthiness of all the CT/PT its associated circuits.[6]

Detailed Diagram for the same is shown below. Figure 1 and Figure 2.

Turbine/Prime mover is run to rated rpm (3000rpm) and then Field breaker is also closed. Before generator ckt breaker three phase shorting is done for performing S.C.C. test by closing isolator. For O.C.C isolator is kept open and voltages are measured. Generator is running but GCB is kept in off condition. This activity is performed in coordination with the transmission testing staff. The three phases shorting at yard and open ckt are performed by them.

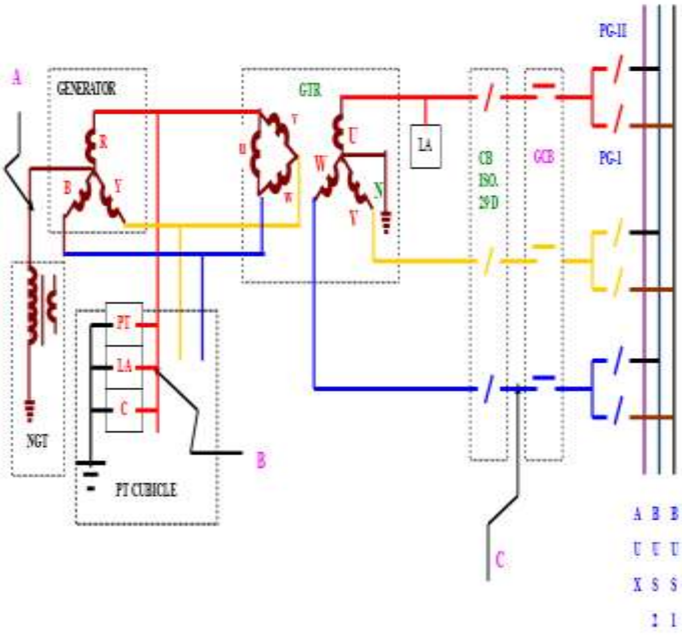

Figure No. 1: Generator dynamic testing

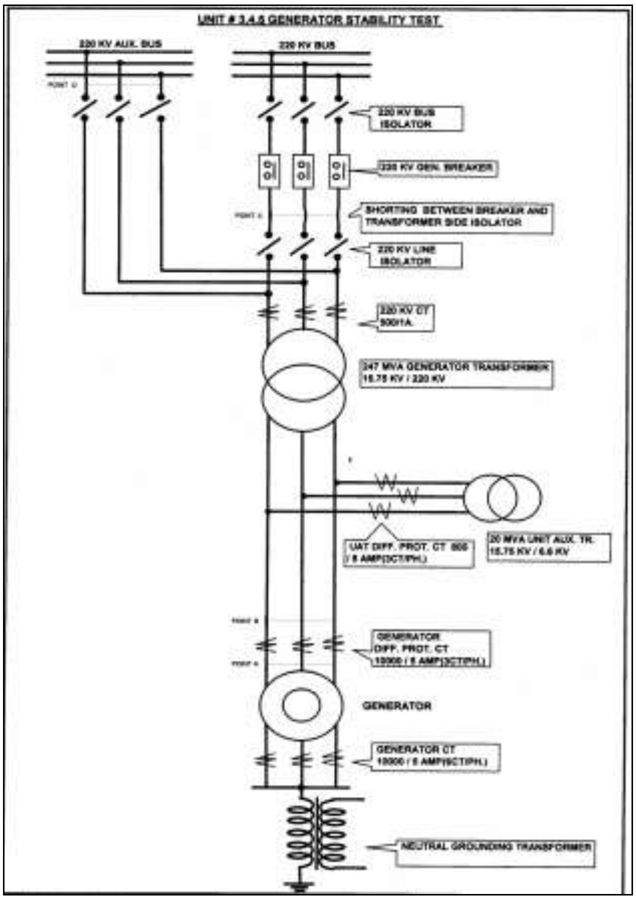

Figure No. 2:Generator dynamic testing

III. PROCEDURE

Dynamic Testing of Generator is performed by following a step by step procedure. There are two parts in dynamic testing of generator. SCC Test and OCC Test. Following abbreviations are used in this procedure.[2]-[3]

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GCB: Generator Circuit Breaker
LBB: Local Breaker Back Up
GTR: Generator Transformer
UAT: Unit Auxiliary Transformer
GCR: Generation Control Room
SOE: Sequence Of events
CT: Current Transformer
VT: Voltage Transformer
AVR: Automatic Voltage Regulator
CB: Circuit Breaker
PT: Potential Transformer
NPS: Negative Phase Sequence
MTR: Master Trip Relay
PCR: Plant Control Room
FB: Field Breaker
GRP: Generator Relay Panel
NGT: Neutral Grounding Transformer

Before actually starting with the dynamic testing following pre checks are to be done.

1. GCB ON/OFF and protection trials are completed with SOE Print outs of PCR.
2. LBB isolation links are removed.
3. Busbar Diff. CT core is shorted by GCR Testing staff.
4. Gen. Trip to Turbine trip command bypassed by I&C-II staff.
5. All other protections of GEN., GTR's, and UATs are in service.
6. Confirm 3 phase shorting is done after CB isolator. (Location 'C').
7. VT Supervision to DISABLE, for the Operation of BACKUP IMPEDANCE Protection (21G1/G2).

DURING SCC TEST

In SCC Test we are going to check the stability of GTR Differential, GTR Ref, Overall Differential, The sensitivity and selectivity of Negative Phase Sequence Protection Relay is also checked.[6]

A) Stability of Gen. Diff., GTR Diff., GTR REF & Overall Diff. Protection during SCC Test

   1. *Roll the machine at 3000 RPM.*
   2. Close the 29 D isolators at switchyard.(location 'C')
   3. Put AVR on manual mode & Close the field breaker.
   4. Increase the current up to 2000 A and note down all CTs secondary currents at GRP, AVR panel and measure the spill currents through Gen. Diff., GTR Diff., GTR REF and Overall Diff. Protection relay in format and confirm the stability of all above relays.
   5. Further increase the generator current and note the current where Minimum impedance relay (Backup Impedance 21G1; Z<2) operates with MTR with Auto tripping of F.B.
      [MICOM GPR-1/2 relay, Ratio of V (AB) Mag. Voltage & IA1 Mag. current (Z<2 set at 1.2 ohm)
   6. Reset MTR, Disable the Backup Impedance protection.
   7. Again close the Field Breaker and Increase the generator current up to 10000 A and again measure all the spill currents through above-mentioned protection relays.
   8. By looping ON GRID contact (at 1U1 panel TB2-69, 70 for GPR-1 and TB2-75, 76 for GPR-2) with Backup Impedance relay 21G2 in operated condition (Z<1 set at 15.9 ohm, this impedance is not possible in SCC Test thus to check operation of 21G2, change Z<1 setting to 3.5 ohm), ensure operation of MTR with Auto tripping of Field Breaker.

B) Sensitivity of Negative Phase Sequence protection relay.

   1. For checking this protection, Interchange R and Y phase CT (CT-D1, TB1- 13 & 15) by shorting links and open the TB link.
   2. Close the field breaker.
   3. Gradually increase the current till NPS Alarm appears. Note down the operating current. [Note down I2 magnitude current ___________, where NPS Alarm appears(NPS Alarm setting is 250mAmp,t=2 sec) and note down Primary Current IA= ----------, IB= ----------, IC= ------------]
   4. Further increase the current up to twice the current of NPS Trip setting.
   5. Wait till the NPS Trip relay operates, I2-100%, ensure operation of MTR with Auto tripping of Field Breaker (Trip setting is 300mA).
   6. Reset all the relays.

DURING OCC TEST

For OCC Test the isolators are to be kept open and then Sensitivity of Generator Stator Earth Fault and Generator Stand By Earth Fault are checked by making single phase to Earth by Earthing rod at PT cubicle and then at Generator Neutral. [6]

C) Sensitivity of Generator Stator E/F (95%) relay

   1. Open the 29 D CB isolators.
   2. With turbine rolling on 3000 RPM and FB is OFF, Now make single phase to earth by earthing rod at PT cubicle (location 'B').
   3. Close the FB and gradually increase the voltage, note down the voltage VN Measured_______, where 95% stator E/F protection relay operates (VN setting is 8V).
   4. Ensure operation of MTR with auto tripping of FB, Reset MTR and Relay.

D) Sensitivity of Generator Standby Stator E/F (51NG) relay

   1. Disable 95% Stator E/F Protection.
   2. Close the FB and gradually increase the voltage till current through CT-P of 51NG relay reaches 150mA (t=1sec), (IN Measured) Confirm the operation of Standby Stator E/F 51NG relay with MTR. Note down the PT voltage__________.

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3. Ensure the tripping of FB, Reset MTR and Relay.
4. Remove the Earthing done in PT cubicle and lock the PT cubicle.

E) Sensitivity of Generator Stator E/F (100%) relay

1. Earth the Gen. Neutral at Neutral cubicle by Earthing rod. (Location 'A')
2. Disable 51NG, and change V<80 inhabit to V<30 for checking 100% E/F protection.
3. Close the FB and gradually increase the voltage, Simulate GCB ON condition for GPR-1&2
4. Note down the voltage VN Measured_______, and VN 3rd<________, where 100% Stator E/F. protection relay operates (VN 3rd < setting is 400mV).
5. Ensure the operation of MTR, tripping of FB, Reset MTR and Relay
6. Normalize the 95% Stator E/F Prot. and remove the GCB ON simulation.
7. Remove the Earthing done in NGT cubicle
8. Ensure the operation of MTR, tripping of FB, Reset MTR and Relay.
9. Normalize the 95% Stator E/F Prot. and remove the GCB ON simulation.

F) Open circuit Test

1. Confirm 29 D CB isolators are Open.
2. Normalize all disabled protections and other settings.
3. Close the FB.
4. Gradually increase the generator voltage in step of 4 KV up to rated 21 KV.
5. Note down the all the three PT voltages at GRP, AVR panel.
6. Note down the synchronizing PT voltage & Voltage across 95% Stator E/F Relay.
7. Trip the FB after reducing Gen. Voltage manually to minimum.

Following normalization to be done after dynamic testing of generator.

1. Inform the GCR testing staff about removal of the 3 phase shorting after 29D CB isolator and Busbar diff. CT shorting.
2. Normalize the Gen. Trip to Turbine trip protection from I&C side. Normalize the LBB links.

IV. RESULTS

- Before SCC Test
- Generator trip to Turbine trip protection is bypassed.

A) SCC Test Readings

Back up impedance relay operated at 4800A
Back up impedance relay timer blocked.

Generator protection relays are tested during shutdown and overhauls of the generator but the complete scheme is not checked. Dynamic testing provides the alternative of checking the overall stability and sensitivity selectivity of generator protection. The project emphasizes on checking the overall protection scheme by dynamic testing yearly or two yearly basic.

Generator dynamic testing measured values of current are shown in Table No.1, 2, 3A,3B. Currents are measured at various relays to check the overall stability and operating characteristics of relays.

RELAY	TB NO. / TTB No.	GEN. Current	
		2000 A	10000 A
OVER ALL DIFF. PROTN (87 GT, MBCH16)	Blk-'F'-S6 (R)	531mA	2.47A
	Blk-'F'-S7 (Y)	531 mA	2.47A
	Blk-'F'-S8 (B)	533 mA	2.48A
	Blk-'F'-S3 (R)	520mA	2.42A
	Blk-'F'-S4 (Y)	523mA	2.43A
	Blk-'F'-S5 (B)	523mA	2.43A
	Blk-'F'-S1 (R)	1mA	38mA
	Blk-'F'-S9 (Y)	1mA	31mA
	Blk-'F'-S10 (B)	1mA	34mA

Table No. 1

RELAY	TB NO. / TTB No	GEN CURRENT	
		2000A	10000A
GTR DIFF. PROTN. (87T, MBCH12)	Blk 'H'-S6 (R)	640mA	2.98A
	Blk 'H'-S7 (Y)	637mA	2.97A
	Blk 'H'-S8 (B)	640mA	2.99A
	Blk 'H'-S3 (R)	633mA	2.95A
	Blk 'H'-S4 (Y)	634mA	2.95A
	Blk 'H'-S5 (B)	635mA	2.96A
	Blk 'H'-S1 (R)	0	24mA
	Blk 'H'-S9 (Y)	0	3mA
	Blk 'H'-S10 (B)	0	3mA
95% Stator earth fault(64G)	Voltage across Relay TB1-16&18 at 3000 rpm	0.692 V	3.271 V

Table No. 2

RELAY	TB NO. / TTB No.	GEN CURRENT	
		2000A	10000A
GEN. DIFF. PROTN. (87 G, SGNH83)	RP1-TB1-9(R)	519mA	2.41A
	RP1-TB1-11(Y)	521mA	2.41A
	RP1-TB1-13(B)	519mA	2.41A
	RP1-TB1-1(R)	518mA	2.40A
	RP1-TB1-3(Y)	516mA	2.40A
	RP1-TB1-5(B)	517mA	2.40A
	RP1-TB1-17(R)	0	0
	RP1-TB1-19 (Y)	0	0
	RP1-TB1-21 (B)	0	0

Table No. 3 A

Table No. 3 B

B) Gen. OCC Test Readings: (AVR)

GEN. KV	AVR PT VOLTAGE			FIELD AMP
	RY CJNO4 TBR-31& 33	YB CJNO4 TBR-33& 35	BR CJNO4 TBR-35& 31	
10 KV	52.9	52.9	52.9	410 A
21 KV	109.4	109.4	109.4	1075 A

	AT 10 KV	*AT 21 KV*
RP2 – TB1 – 16 & 18	*1.496 V*	*2.9 V*

Table No.4

- RESIDUAL PT VOLTAGES AT 3000 RPM (GTR side isolator in Open condition)

GEN KV	FIELD AMP	VT1 21KV / 110V	VT2 21KV / 110V	VT3 21KV / 110 V
10 KV	*410 A*	*52.1*	*52.3*	*52.7*
21 KV	***1075 A***	*109*	*109*	*109*

VT1 21KV / 110 V	*VT2 21KV / 110 V*	*VT3 21KV / 110 V*	
109 V	*109 V*	*109 V*	*Open CKT*
109 V	*109 V*	*109 V*	
109 V	*109 V*	*109 V*	

Table No.5

- *Voltage Across Stator E/F Relay (64 G) AT 21 KV*

Table No.6

Gen. OCC Test Readings

Table No.7

Generator transformer side isolators kept in open

RELAY	*TB. NO / TTB. NO*	*GEN Current*	
		2000A	*10000A*
PROTECTION RELAYS 51G , 40G, 646G1, 46G2 , 21 G , 78 G, 78GY	*Rel. 51G Tr. No. 7(Y)*	*518mA*	*2.41A*
	Rel. 51G Tr.No. 9(B)	*519mA*	*2.40A*
	Rel. 40G Tr. No. 9(R)	*518mA*	*2.42A*
REVERSE POWER / FORWARD POWER PROTN. 32 G1, 32 G2 , 37G	*Blk 'B'-S3(R)*	*530mA*	*2.48A*
	Blk 'B'-S5(Y)	*532mA*	*2.47A*
	Blk 'B'-S7(B)	*533mA*	*2.48A*
Stdby E/F PROTN. (51GTN)	*Blk 'J'-S9*	*0.31mA*	*1.4mA*
GTR REF PROTECTION(64GT, MCAG34)	*TB1-57 (R)*	*109mA*	*511mA*
	TB1-58 (Y)	*109mA*	*512mA*
	TB1-59 (B)	*109mA*	*510mA*
	TB1-53 (R)	*110mA*	*508mA*
	TB1-54 (Y)	*108mA*	*508mA*
	TB1-55 (B)	*109mA*	*508mA*
	Blk 'P'-S3(R)	*0*	*0*
	Blk 'P'-S4(Y)	*0*	*0*
	Blk 'P'-S5(B)	*0*	*0*
GENERATOR BACKUP O/C (51GT) & LBB (50Z)	*Blk 'J'-S3(R)*	*111mA*	*519mA*
	Blk 'J'-S5(Y)	*111mA*	*519mA*
	Blk 'J'-S7(B)	*111mA*	*519mA*

condition and readings taken at AVR panel and also at generator protection panel Table No 4, 5, 6, 7.The readings are found in unison with the design parameters. The generator dynamic testing is successful and generator protection scheme stability and healthiness is checked.

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V. CONCLUSION

Operation of Generator Differential and Overall Differential Protection tested dynamically under actual fault conditions Safe and fine control through excitation is achieved thus Healthiness of Excitation system is also proved. Sensitivity and operation of Generator Stator Earth Fault and Generator Stand By Earth Fault are proved. Thus healthiness and operation stability of generator protection system is confirmed. O.C.C and S.C.C characteristics are obtained.

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