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Excitation Control during Short Circuit Test Sequence of 1500 MVA Short Circuit Generator

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Abstract— **Short circuit (S.C.) generator is very much different from the conventional generators used in power generating stations. Driving S.C. generator and extracting power from it is indeed a specialized job. Power drawn from S.C. generators during test is much high in magnitude hence it has to be taken care that the supply grid should not to be loaded during the period of short circuit. Normally generators are driven with different kinds of prime mover. With the advent of the solid state devices it became possible to run a generator even without a prime mover. This paper describes the control techniques used during different Test Sequences for a 1500 MVA, 12.5 kV, 3000 rpm, 50 Hz S.C. Generator. These techniques are verified practically on actual test equipments and supported with the resultant waveforms. This generator is functional at Bhopal unit of Central Power Research Institute.**

***Keywords*—Short Circuit Genertator, Short Circuit Test Sequence, Excitation Control**

I. INTRODUCTION

A Synchronous machine can be run as motor or generator depending on the input conditions [1]. Synchronous machine is not a self-starting machine. All synchronous machines require some power to excite its field winding which is called exciter. The exciter is the backbone of the machine control system. Excitation systems have a powerful impact on dynamic performance and availability as generator; it ensures quality of generator voltage and reactive control power. The field, when excited by dc magnetizing current and rotated past the stationary conductors of the stator of the synchronous generator, causes voltage to be generated at the synchronous generator terminals. The amount of excitation required to maintain the output voltage constant is a function of the generator load. As the generator load increases, the amount of excitation increases.

Reactive lagging power factor loads require more excitation than unity power factor loads and loads with leading power factor require less excitation than unity power factor loads.

After the invention of solid state devices like SCR (or Thyristor) it became possible to replace rotary exciter with the static one. Static excitation provides faster transient response than rotary exciters [3] [4].

Fig.1 shows the single line diagram of 1500 MVA, 12.5 kV, 3000 rpm, 50 Hz short circuit generator of CPRI, Bhopal whereas, generator excitation circuit (GEX) is as per Fig.2.

II. GENERATOR EXCITRATION SYSTEM

Field excitation of the generator is fed through a static panel equipped with the following (fig.2):

- A SF_6 CB used in the primary side of the transformer to isolate the complete bridge from the power network.
- A 5.5MVA double winding power transformer to supply the bridges.
- Two full wave Thyristor Bridge converter.
- A control cubicle for monitoring various parameters and provides thyristor pulses.
- A DC Circuit Breaker isolates the bridge from the rotor whenever required.
- A DC Loop contactor to ensure the discharge of the rotor energy after DCCB opening.
- Field current and voltage measurement transducers for excitation current regulation.

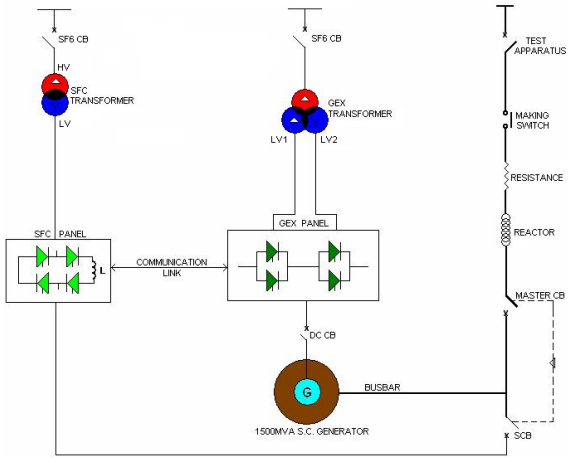


Fig.1: Single Line Diagram of 1500 MVA Short Circuit Generator.

GEX ensures the following functions

- Regulation in Motor Mode
  - i. Pulse Link operation
  - ii. Synchronous operation

- Regulation in Generator Mode
  - i. Stator voltage control
  - ii. Flux control
  - iii. Excitation current control during the short circuit test sequences.

III. REGULATION IN MOTOR MODE

A. *Regulation in Pulse Link Mode*

Initially machine is started as a synchronous motor. Position of the rotor is determined by feeding excitation pulses from the GEX panel. After sensing the rotor position, power at very low frequency pulses from the Static Frequency Converter (SFC) panel (Fig.1) is fed to stator winding in a precised controlled manner. With this the rotor shifts from its stationary position and tries to align with the stator magnetic axis. When the next pulse is applied the stator magnetic axis shifts so as rotor also. In this way rotor gets its rotation and its speed is gradually increased with increase in frequency of stator pulses. This starting method is called pulse link mode. In this mode the stator supply frequency is stepped up from 0 to 2.5 Hz to keep the rotor at 150 rpm.

B. *Regulation in Synchronous Mode*

To take the machine up to rated speed i.e.3000 rpm the frequency is increased gradually to 50 Hz that is the rated speed. This is called synchronous mode operation. Fig-3 shows the Block Diagram of excitation during Motor mode. At very low speed the exciter is only current regulated. When the speed is increasing (so the back e.m.f.) and becomes high enough then the flux regulator is used, because flux is deduced from voltage measurement.

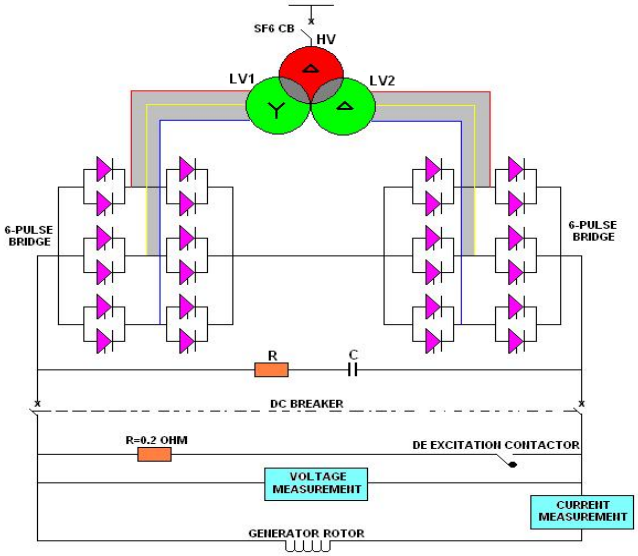


Fig-2 Single Line Diagram of GEX.

IV. REGULATION IN GENERATOR MODE

To get the desired Short Circuit Voltage and Short Circuit Current, Excitation control required in Generator Mode. Short Circuit tests are conducted based on the rating and type of the equipment. Various short circuit sequences are programmed with the STP (Synchronous Test Processor).

A. *Short Time Duration S.C Sequences*

To obtain short time duration tests (0-200 ms), the initial stator voltage and ceiling ratio are preset to the desired values. The short-circuit sequences are programmed in STP.

Fig.4 shows the excitation control block diagram during short circuit test sequence. The generator output voltage and current are continuously compared in a close loop cycle with the preset reference values. The converters receive firing angle of the thyristors from the controller, based on ceiling ratio and comparator output [2].

B. *Long Time Duration S.C Sequences*

For these sequences the time duration is set by the STP is in the range of 1sec to 3 sec. Other than setting the initial stator voltage and ceiling ratio, in this case we also have to set the short circuit current reference (SCR). The SCR is given in long duration short circuit test to minimize the drop in the current values at the end cycles due to armature reaction.

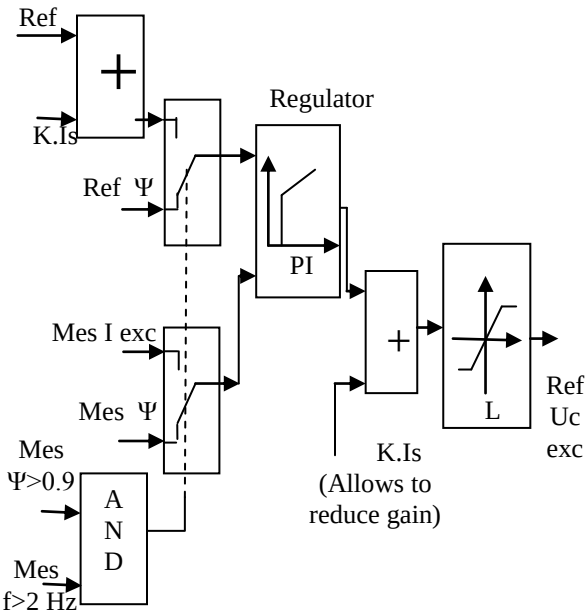


Fig-3: Block Diagram of Excitation Control during Motor mode.

The system normally runs at rated speed in motor mode. Conversion to the generator mode is done before drawing the power from it. The steps for the mode conversion and short circuit test are as follows:

- Blocking the pulses of SFC & GEX thyristors so that no power is drawn from grid.
- Opening a circuit breaker between SFC output and stator input to make physical isolation.
- Release the gate pulses of GEX thyristors so that field power is fed to rotor according to the preset stator reference voltage.
- As the machine was in full speed and disconnected from the grid it will change to generator mode when it gets rotor excitation.
- The generated output is fed to the test object through certain protective and measuring devices.

After each operation, there is little drop in the speed. That is recovered up by changing the mode from generator to motor to attain 3000 rpm and it is ready for the next cycle of operation.

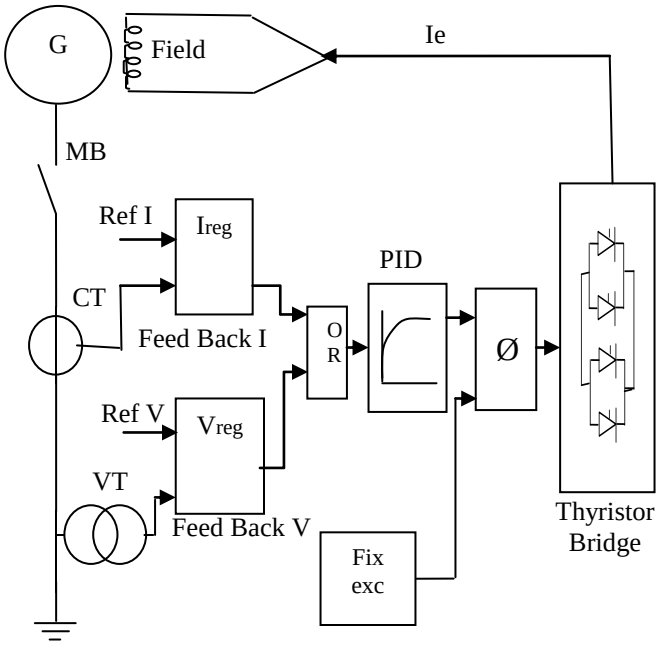


Fig.4: Block Diagram of Excitation Control during Generator mode

C. Setting of sequence of operation in synchronous test processor (STP) for a short circuit test – an example.

The following events are sequentially programmed (Table 1) in the STP during short circuit test:

Table 1 Sequence setting

Event No	Particulars to Start
01	Motor to Generator Mode
02	Excitation On
03	Master Circuit Breaker ON
04	Recording system ON
05	Protection Blocking Activated
06	Make Switch ON
07	S.C. Current Regulation ON
08	S.C. Current Regulation OFF
09	Master Breaker OFF
	Excitation OFF
10	Protection Blocking Deactivated
11	Generator to Motor Mode
12	End of Sequence

The above sequences can be depicted as chronograms shown in Fig.5.

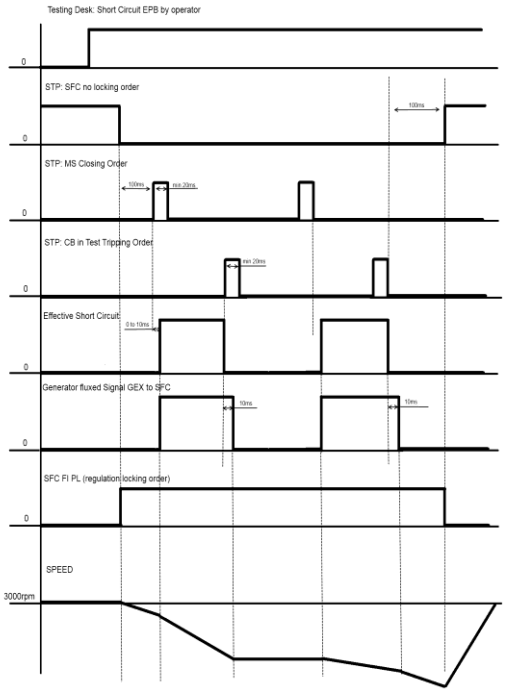
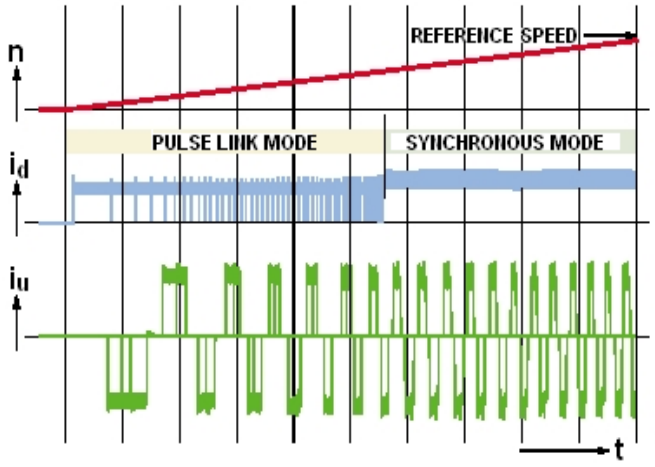


Fig.5: Chronograms of SC Test sequence.

V. RESULTS

A. *Motor Mode*

The Fig.6 explains how the machine speeded up smoothly to the reference speed with the help of SFC and controlled field regulation in Pulse link mode as well as Synchronous mode.



n – rpm of synchronous machine
id – direct current in intermediate link
iu – phase current in winding U of synchronous machine

Fig.6. Waveforms during Starting.

B. *Generator Mode*

In generator mode the regulator acts with a feedback from stator current reference and actual stator current. The same is represented in Fig.7.

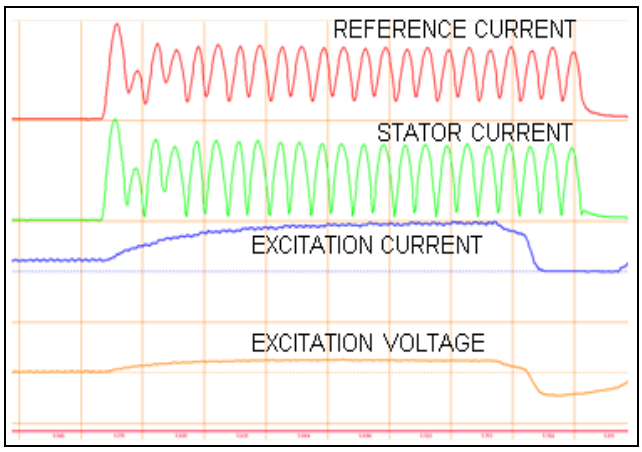


Fig-7. Waveforms during Generator Mode.

Some of typical short circuit duty cycles performed using this machine were recorded and shown in fig. 8 & 9.

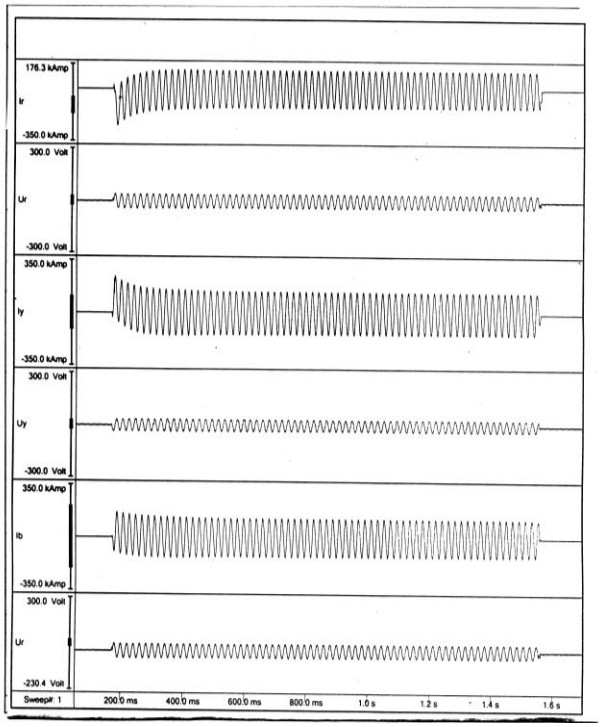


Fig.8. Long duration Test on CT.

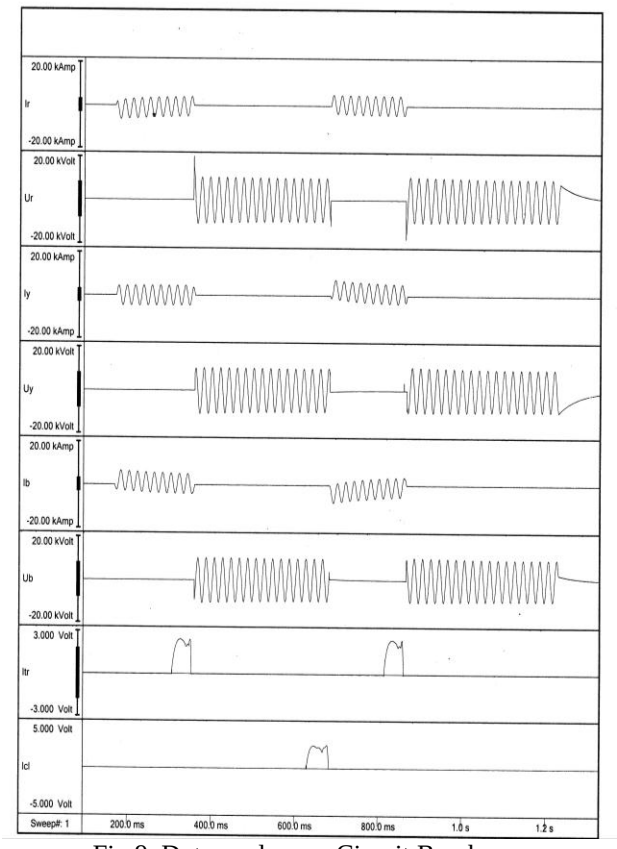


Fig.9. Duty cycle on a Circuit Breaker.

VI. CONCLUSION

GEX control System plays a key role during short circuit test sequence. It completely controls the desired value of stator voltage and current by regulating the field excitation which is shown exactly in the results. The GEX can also distinguish between normal and abnormal condition with an alarm or a trip signal.

ACKNOWLEDGMENT

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