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Depiction of New Static - Starting and Excitation Systems to start Short Circuit Generators

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Abstract

Short circuit plants are used mainly for testing and R&D activities. These plants are faced with high maintenance and down time due to the excitation system. Motor driven rheostats, rotating exciter failures, Commutator and carbon brushes deterioration, and disturbances in bearing location are just a few of the typical problems of these aged short circuit plants. The result is long down time of the generator system. The replacement of the rotating exciter and associated equipment for static excitation systems provides the positive solutions to these problems. The static exciter offers the design flexibility of easy retrofit for both small and larger rotating exciter systems. Additionally, it eliminates the maintenance overhead common to the brush type exciter. This paper will discuss the static excitation system of 1500 MVA, 12.5 kV, 3000 rpm, 50 Hz Short Circuit (S.C) Generator. Also explain how the S.C.Generator reaches 3000 rpm and its resultant wave form. This generator is functional at Bhopal unit of Central Power Research Institute.

Keywords

Static Frequency Converter, GEX, Short Circuit Generator, Thyristor Graetz Bridge.

1. Introduction

Short circuit 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.
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]. The principle and operation of a new excitation system called as “GEX”.

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 basic tasks of the excitation system are stable supply of the synchronous machine rotor with a D.C.current, control of the set-point value of the generator terminal voltage and control of the stable reactive power flow.

When compared with another types of the excitation systems, static excitation system has the following advantages:

- Higher control speed
- Short de-excitation time
- Higher reliability
- Higher availability and redundancy
- Higher efficiency
- Optimal protection of the field winding
- Rotating parts are eliminated
- Lower maintenance costs
- Easier build-in in the new as well as in the plants under reconstruction
- Simple adaptability to the synchronous generators of the different sizes and types
- Electrical braking control possibility
- Dimensions are independent of the machine size and speed.

The excitation system is equipped with a microprocessor control system that has a number of advantages over the old analogue solutions:

- High accuracy and reliability
- High speed
- Higher communication and automation level
- Simple parameters settings and changes without interfering with hardware.
- Increased internal supervision, diagnostics and self-diagnostics possibilities
- Easier design and documentation
- Easier testing and commissioning
- Easier maintenance

Above-mentioned increases the quality, reliability and availability of the excitation system as well as the whole plant what decreases labour and maintenance costs.

2. Static Frequency Converter (SFC)

The function of the Static Frequency Converter (SFC) is to start the 1500 MVA, 12.5 kV, 3000 rpm, 50 Hz short circuit generator. The total starting time up to 300rpm is 5 minutes. SFC is equipped with the following major equipments (fig.1)

1. A switchgear protects and isolates the equipment from the network in the case of a fault or stopping of the SFC.
2. A power transformer supplies the SFC.
3. A thryristor Graetz bridge named network bridge (NB).
4. A DC link reactor
5. A thyristor Graetz bridge named Machine bridge (MB).

2.1 Description of the main components of SFC System.

2.1.1 Thyristor Graetz Bridge

There are two thyristor Graetz bridges, in these one is connected to the network supply called network bridge (NB) and the other one connected to machine side called machine bridge (MB). The function of the network bridge is to rectify the supply voltage. The function of the machine bridge is to supply the motor at variable voltage and frequency.

The basic power modules includes high power thyristors with a silicon pellet and its rated off state and reverse blocking voltages depends on the SFC rating. Each thyristor is fitted in between double heat sink press pack with their RC components.

2.1.2 DC link reactor

DC link reactor limits the current ripple in the DC link due to the difference in the instantaneous value of the machine and network bridges. It also limits a possible fault current.

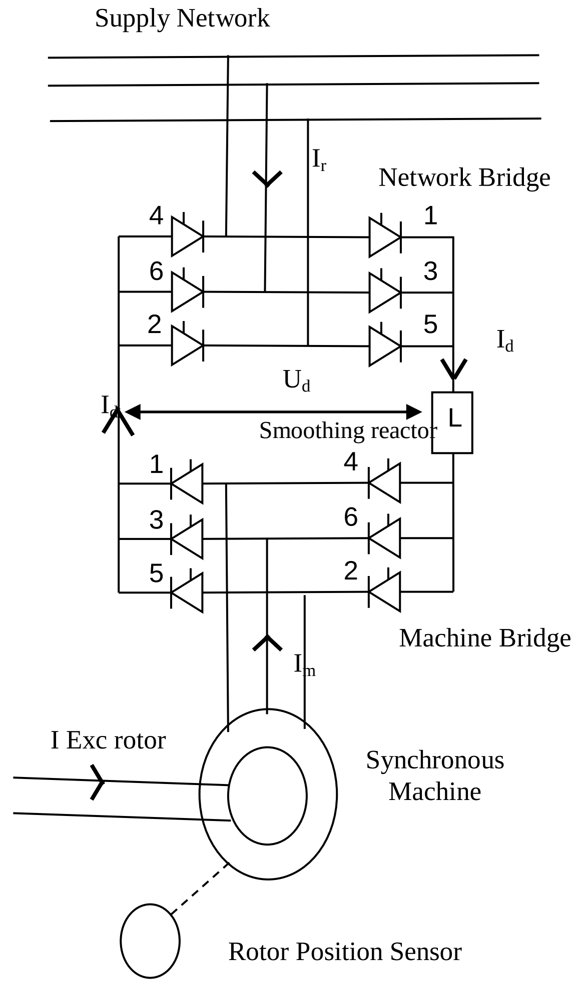


Fig.1: Block diagram of SFC

3. Generator excitation system

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

a. A Circuit Breaker is used in the primary side of the transformer to isolate the complete bridge from the power network.
b. A power transformer is used to supply the bridges.
c. Two full wave Thyristor Bridge converter.
d. A control cubicle for monitoring various parameters and provides thyristor pulses.
e. A DC Circuit Breaker isolates the bridge from the rotor whenever required.
f. A DC Loop contactor to ensure the discharge of the rotor energy after DCCB opening.
g. Field current and voltage measurement transducers for excitation current regulation.

GEX ensures the following functions [1]

- 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.

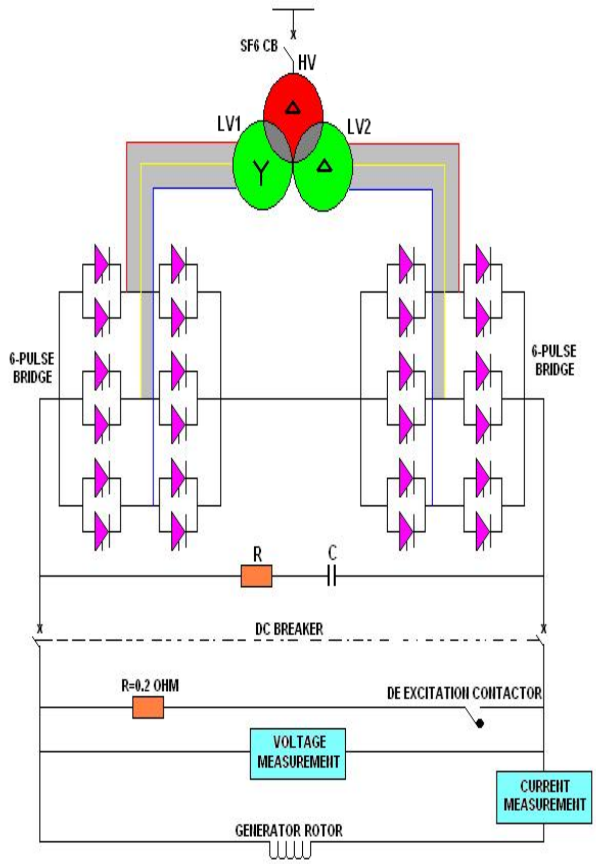


Fig 2: Single line diagram of GEX [5]

3.1 Description of the main components of GEX System

3.1.1 Excitation transformers

The excitation transformer reduces the supply voltage to the level required for excitation. An oil-type of transformer is generally used. The thermal equivalent power of this three phase transformer and its transferred power during one second is also depends on the installed capacity of GEX.

3.1.2 Thyristor bridge converter

The DC loop bridge is the result of the assembling of two identical thyristor Graetz Bridges. Both bridges are installed in a ventilated cubicle, which accommodates the basic power modules include power thyristors with a silicon pellet and its rated off state and reverse blocking voltages depends on the installed capacity of GEX. Each thyristor is fitted in between double heat sink press pack with their RC components.

3.1.3 DC Loop Circuit Breaker and Contactor

The circuit breaker carries out the switch on and off of the DC loop. The circuit breaker has to isolate the generator's rotor from the thyristors bridges whenever required. The DC loop contactor switch on when the DC loop circuit breaker switch off. During its closing time, to prevent any over tension due to the discharge of the rotors reactor, the thyristors are fired.

4. Starting methodology S.C. Generator

4.1 Operation of Graetz bridge of SFC

The value and the sign of the U_d d.c voltage shown in fig.1 is monitored by the closed-loop control devices. When this voltage is positive (e.m.f), then the bridge is acting as a RECTIFIER. It takes power in the form of alternating currents from the supply network or from the machine as the case may be, and returns it to the intermediate loop in the form of direct – current. When this voltage is negative, the bridge is acting as an INVERTER [2][4]. It takes power in the form of direct current from the intermediate loop and returns it to the supply network or to the machine, as the case may be, in the form of alternating currents at the relevant frequency.

The operation of the Graetz Bridge is as follows. Graetz Bridge operates so that only two legs in the bridge simultaneously deliver the Id current. The following six configurations for two legs in a state of conduction take place successively are 1-2, 2-3, 3-4, 4-5, 5-6 and 6-1. Each configuration lasts 60 degrees electric and of course recurs every 360^0.

During Synchronous operation i.e high speed operation the Machine Bridge is self commutated. In order to change, for instance from (1-2) to (2-3), it is sufficient to transmit a firing pulse to the gate of (3). During this operation the level of the machine e.m.fs is sufficient for the current in (1) to turn itself off while (3) takes the load. Finally, it should be observed that the Graetz bridge needs a sufficient a.c. voltage at its terminals to operate normally (in self – commutating mode). In fact, the voltage across the machine is proportional to its speed and in particular it is at zero when the machine is at a standstill [3]. This is the reason why operation of the SFC is broken down into two different modes are

1. High – Speed Operation i.e. Synchronous Mode.
2. Low – Speed Operation i.e. Pulsed Link Mode.

With the help of these two operations short circuit generator achieves its rated speed i.e. 3000 rpm very smoothly. These two modes of operations are plays vital roles during starting of the short circuit generator.

4.2 Pulse link operation

Initially machine is started as a synchronous motor. Position of the rotor is determined by feeding excitation pulses from the GEX panel (fig.2). 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 (pulse link mode speed can be varied depending upon the requirement of the customer) [5]. Hence the purpose of this pulse link operation is to make the synchronous machine speed is upto 150 rpm very slowly. The same thing also can be observed in fig.4.

4.3 Synchronous mode operation

In the case of pulse link operation speed goes upto 150 rpm only. To take the machine up to rated speed i.e.3000 rpm the mode of operation is synchronous mode of operation. In this operating mode 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 [1][5].

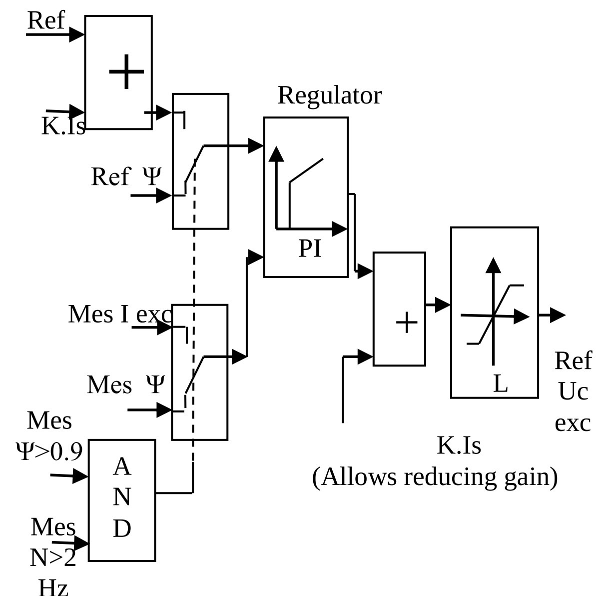
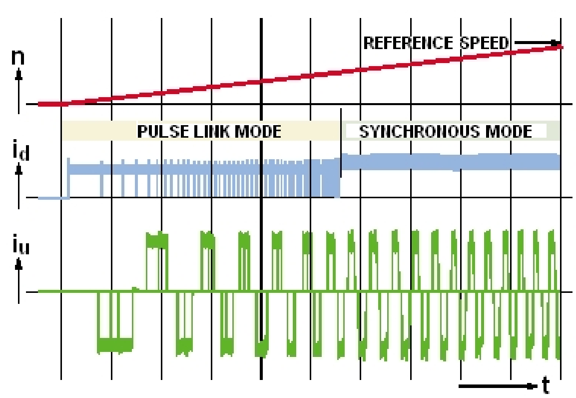


Fig-3: Block Diagram during starting of S.C.Generator[1]

4.4 Resultant waveform

The fig.4 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.

From the figure can be observed that during the synchronous mode current I_d is continuous it means sufficient voltages are available across the thyristor terminals. Because of this thyristors are in self commutation mode, hence current I_d is continuous. The same it is not possible during pulse link mode of operation because of insufficient voltages across thyristor terminals. The same thing can be observed in fig.4.



n – rpm of synchronous machine

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

Fig 4: Waveforms during S.C.Generator starting.[1]

5. Conclusion

A new concept has been introduced in CPRI, Bhopal for starting of 1500 MVA, 12.5 kV, 3000 rpm, 50 Hz short circuit generator. With these new technologies can save a lot of time and amount for maintenance activities, as it does not have any rotating parts. Adopting new technologies is always helps to improve plant availability factor.

References

[1] Arun Kumar Datta, G.Venkateswarlu, N.R.Mondal, M.A.Ansari - Excitation Control in Motor mode of Short Circuit Generator, AICON-2012, January, Durg, Chattisgarh.
[2] Tsorng-Juu Liang, Jiann-Fuh Chen, Ching- Lung Chu, Kuen-Jyh Chen, "Analysis of 12 Pulse Phase Control AC/DC Converter", IEEE 1999 International Conference on Power Electronics and Drive Systems, PEDS'99, July 1999, Hong Kong.
[3] Jose R. Rodriguez, Jorge Pontt, Cesar Silva, Eduardo P. Wiechmann, Peter W. Hammond, Frank W. Santucci, Roderigo Alvarez, Roderigo Musalem, Samir Kouro and Pablo Lezana, "Large Current Rectifier: State of the Art and Future Trends" IEEE Transactions on Industrial Electronics, Vol. 52, No. 3, June 2005.
[4] Akagi Hirofumi, "Large Static Converters for Industry and Utility Applications" Proceedings of the IEEE, Vol. 89, No. 6, June 2001.
[5] B. V. Raghavaiah, N. R. Mondal, Arun Kumar Datta, Dr. Manisha Dubey - Motor less operation of short circuit generator: a CPRI perspective, ICEPES-2010.

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