



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 11, November 2023

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

ijirset@gmail.com

www.ijirset.com

Energy Conversion in a Short Circuit Generator

Sandeep Singh, Arun Kumar Datta, Arvind Pandey, Arpit Singh, Abhishek Verma

Engineering Officer-2, Central Power Research Institute, Bhopal, India

Joint Director, Central Power Research Institute, Bhopal, India

Engineering Officer-4, Central Power Research Institute, Bhopal, India

Engineering Officer-2, Central Power Research Institute, Bhopal, India

Engineering Officer-2, Central Power Research Institute, Bhopal, India

ABSTRACT: Short circuit generators are the type of generators which are mainly used for the short circuit testing of various electrical equipment. These are specially designed to provide a very high amount of power over a very short duration of time by using the concept of energy conversion. Energy is at first converted from electrical to mechanical then it is stored in its mechanical form and again it is converted from mechanical to electrical form. Short circuit generator differs from the conventional generator mainly in a way that it cannot provide such huge amount of power as is the rating of short circuit generator for long duration of time but such is not the case with conventional generators. Supply of continuous power increases the energy output and because of this reason energy which is fed to the conventional generator is very large when compared to the short circuit generator. This paper discusses the brief theory of short circuit generators and the evaluation of such energy conversion.

I. INTRODUCTION

Short circuit test is one of the most significant tests for electrical equipment, which is done by simulating the actual fault which may happen after the installation of electrical equipment in the field. This test is conducted by short circuit laboratories, which might be either grid based or generator based. Central Power Research Institute (CPRI), Bhopal has two such laboratories which are catering the testing needs of power sector of not only India but other countries also. Out of those two laboratories, one is a grid based laboratory of 100 MVA capacity, while the other one is generator based laboratory of 1250 MVA capacity [Fig. 1]. Smaller capacity (100 MVA) laboratory draws the power for short circuit test directly from the grid causing a voltage dip which is negligible for the power system of that grid. There is a setup in which power is being tapped directly from 132 kV transmission line for the operation of 100 MVA short circuit laboratory. Voltage dip in the transmission line remains negligible as long as the power drawn from it is not very large or the fault level of that system is high. For high power short circuit test, laboratories cannot draw power directly from the conventional grid having lower fault level otherwise noticeable voltage dip will occur causing the instability in power system. Generator based short circuit laboratory of CPRI Bhopal has two short circuit generators [Figure 2, Figure 3]. Rating of each generator is 12.5 kV, 69 kA, 1500 MVA. Both these generators differ in the manner of how their starting mechanism and excitation system works. Brief overview of these short circuit generators and flow of energy in them has been discussed in this paper.

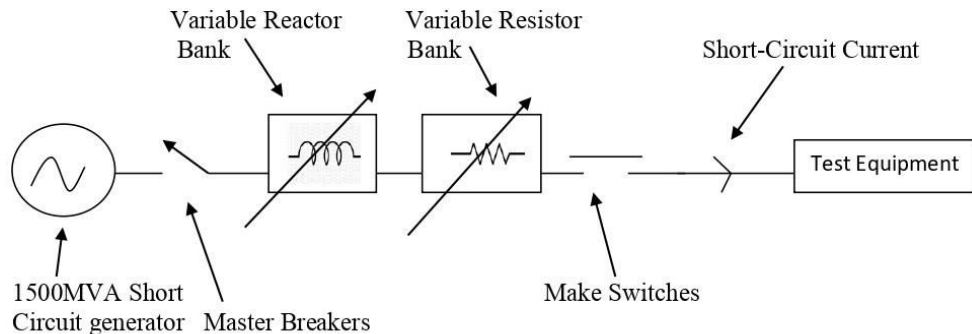


Fig. 1 :- Generator based short circuit testing

II. PRINCIPLE

Working principle of short circuit generator is very different from that of the conventional generator. Short circuit generator delivers energy intermittently during its running time. It only acts as a generator for a very small duration of time during which short circuit current flows which is less than 1 second in most cases and 3 seconds in some cases.

Motor driven short circuit generator (G1) is started by means of a power drive (1600 KW Induction motor). Excitation to the rotor of this generator is given by means of separate DC generator which is self-excited for tests involving the transfer of small power and separately excited for large amount of power.

The other generator (G2) is started by means of static frequency converter (SFC) [1]. It involves the rectification of input supply by converter and inversion by means of thyristors controlled inverter. Controlled switching of thyristors is used to vary the frequency of output AC supply and achieve the start of short circuit generator as a motor using variable frequency method [2]. Lastly when the rotor is rotating at a constant speed of 3000 rpm and the frequency of output voltage from SFC is 50 Hz, magnetic locking happens between rotor poles and the rotating field due to AC output of SFC. The excitation to the rotor of this generator is given by 12 pulse converter [3, 6]. This converter reduces the harmonic content of DC to a very low value.

When excitation is given to the rotor rotating at rated speed and the short circuit test is taken on a test sample, before the flow of short circuit current the starting mechanism is disconnected from the power supply for both G1 and G2 [4]. At the same time excitation system is disconnected from the power supply only for G1. This is done in order to avoid the undesirable possible voltage dip in the power system causing its instability. After the disconnection from main power supply the rotor is rotating on its own due to its property of inertia and it is also getting its required excitation to form the magnetic poles and hence resulting in the formation of rotating magnetic field. This field induces the voltage in the stator windings as per the equation (1).

$$E = (K)(\phi)(f)(N) \quad \text{equation (1)}$$

E = Output Voltage across stator terminals
 K = Constant
 ϕ = flux per pole
 N = Number of turns
 f = Frequency

In this generation of voltage the rotor is disconnected from the starting mechanism and it is rotating only due to the stored kinetic energy due to its property of inertia. When the short circuit current flows, some amount of kinetic energy gets converted into the electrical energy. This decrease in kinetic energy results in the decrease of speed of rotor. Because of this decrease in speed, the frequency of output voltage does not remain same in the whole duration of current flow in short circuit test and also various Indian as well as international standards allows a fair amount of tolerance in the frequency of such short circuit tests. The output voltage is controlled by varying the excitation or ϕ (flux per pole) as it is the only preferable variable.



Fig.2 1500MVA, 69kA, 12.5kV Short Circuit Generator with DC generator excitation system (G1).



Fig. 3 1500MVA, 12.5kV, 69kA Short Circuit Generator with motor less excitation system (G2).

III. FLOW OF ENERGY

Initially, energy enters into the system through a 33 kV Grid substation of CPRI Bhopal. It supplies energy to both starting mechanism and excitation system of short circuit generators. Electrical energy supplied to the short circuit generator is at first stored as mechanical energy in the rotor due to its property of inertia. This electrical energy converted to mechanical energy remains stored in the rotor as long as short circuit generator behaves as a motor [5] (in case of G2) or it is running in idle mode through a power drive (in case of G1). When the short circuit current is supposed to flow in a short circuit test the machine is transferred from motoring mode (G2) or idle mode (G1) to generating mode by disconnecting it from the input supply and after that disconnection short circuit test is taken.

During this short circuit test energy conversion takes place again from kinetic to electrical (Fig. 4). Due to the current flow in stator windings a phenomenon called armature reaction occurs which produces an opposing magnetic field to that of the rotor. Field due to armature reaction decreases the kinetic energy and hence the speed of rotor. After this conversion electrical energy is applied to the test sample in the form of short circuit MVA for a specified duration of time. So it is just the conversion of energy from one form to another form with armature reaction giving an opposing magnetic field and force during this conversion.

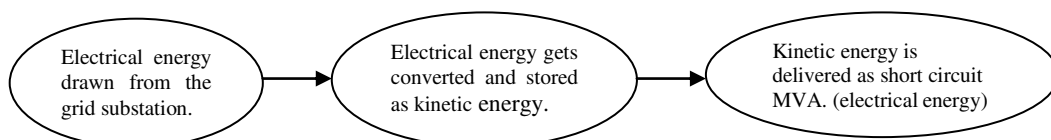


Fig. 4 Flow of energy in short circuit generator



IV. OBSERVATION AND RESULTS

In the observations discussed, energy has been traced from the short circuit generator G2 to the short circuit test laboratory. After energy is supplied to the generator, it is running with some kinetic energy stored in it. For the calculation of that stored kinetic energy, the required data of the rotor (moving part) of short circuit generator G2 is mentioned in the below Table 1 [7].

Rotor	Mechanical characteristics
Mass	36100 kg
Radius	0.55 m
Length	8.05 m

(Table 1: Mechanical characteristics of the rotor of G2)

For the calculation of energy stored in the moving part of a short circuit generator the length between the couplings has been taken as the length of cylinder and retaining ring’s diameter has been taken as the diameter of the cylinder. So for this cylindrical shaped rotor, stored kinetic energy is given by,

$$K = \frac{I (w^2)}{2} \quad \text{equation (2)}$$

- I = Moment of inertia of the rotor
- w = angular speed of the rotor
- K = Kinetic energy stored in the rotor

If a cylinder is rotating with horizontal line as its axis then its moment of inertia is given by the below mentioned equation (3)

$$I = \frac{M (R^2)}{2} \quad \text{equation (3)}$$

- M = Mass of the rotor
- R = Radius of the rotor

By using the above mentioned expression (3) and data of mechanical characteristics in Table 1, the moment of inertia of the said rotor can be calculated

$$I = 5460.125 \text{ kg-m}^2 \quad \text{equation (4)}$$

With the above mentioned value of moment of inertia equation (4) and using equation (2), kinetic energy of the rotating body can be calculated at a rated speed of 3000 rpm or at an angular speed of 314 radian/second

$$K = 269.17 \text{ Mega-Joule}$$

So, at it’s rated speed of 3000 rpm, short circuit generator is having a kinetic energy of 269.17 MJ stored in it. Out of this energy only partial amount of energy is extracted and converted into electrical energy. If by some means we convert more kinetic energy into electrical energy that will decrease the rotating speed of rotor to a further low value which will result in a lower value of frequency for the output voltage. Such low values will violate the tolerances given for frequency in various Indian and international standards.



Fig. 5 Power transformer under short circuit test in CPRI, STDS, Bhopal.

Sample	RPM after the short circuit test	Reduced Kinetic energy of the rotor (O)	Initial Kinetic energy at 3000 rpm (I)	Reduction in kinetic energy (I-O)
Transformer 1	2886	249.10 MJ	269.17 MJ	20.07 MJ
Transformer 2	2888	249.45 MJ		19.72 MJ
Transformer 3	2922	255.36 MJ		13.81 MJ

(Table 2: Reduction in speed and kinetic energy after short circuit test via G2)

Sample	Voltage	Current	Short Circuit MVA	Time duration of shot	Electrical Energy delivered
Transformer 1	3.42kV	6.4kA	37.93	0.520S	19.73MJ
Transformer 2	0.63kV	68.2kA	74.74	0.258S	19.28MJ
Transformer 3	0.44kV	32.3kA	24.79	0.525S	13.02MJ

(Table 3: Electrical parameters and energy for test samples in a short circuit test via G2)

When a short circuit test is taken on a sample certain kinetic energy of the rotor is absorbed and gets converted into electrical energy. This results in the sudden decrease of speed of rotor. For the calculation of change in kinetic energy, certain data with calculation is mentioned in Table 2.

In Table 2, reduced kinetic energy has been calculated using equation (2) and the reduction in kinetic energy has been calculated by subtracting that energy from the initial energy of rotor 269.17 MJ at 3000 rpm. This reduction in energy is the value which has been extracted from the rotor, converted into electrical energy through armature reaction phenomenon and applied to the test sample in the short circuit laboratory as the short circuit MVA.

Electrical energy applied to the test sample can be calculated by using equation (5)

$$E = \sqrt{3}(V)(I)(T) \quad \text{equation (5)}$$

E = Electrical energy applied to the test sample

V = Voltage applied to the test sample

I = Current applied to the test sample

T = Time duration of the short circuit current

Electrical energy consumed has also been calculated for the same sample using equation (5) as given in TABLE 3

In the above table, electrical energy applied has been calculated for different transformers as the test samples in the short circuit test (Fig. 5). It is evident that since the applied electrical energy is different for different transformers, so the consumed kinetic energy will also be different.

The difference between the released kinetic energy from the rotor of short circuit generator and the absorbed electrical energy by the test sample can be understood by observing the equivalent circuit of the system (Fig. 1). A small part of

the electrical energy is consumed by the winding resistance of the stator of SC generator, resistance of the bus bars and other connections.

As analyzed in case of short circuit generator G2, a fair part of energy is also lost when there is a time lag between the opening of starting mechanism switch and the generation of short circuit current as well as the generation of short circuit current and the closing of starting mechanism switch. It has been noticed that there is a delay of approximately 12 seconds in each. So that total time delay causes the speed of generator to decrease by some amount and hence some amount of kinetic energy is lost in that manner due to various frictional forces

V. CONCLUSION

It has been observed by following the conversions of energy in our short circuit generator G2 that electrical energy at first is drawn from the 33kV substation and the same energy is converted as well as stored as mechanical energy into the inertia property of the rotor. When the short circuit test is taken on a sample, a part of that energy got converted into the electrical energy to be applied as short circuit MVA as a measure of quality check by testing.

This case study gives a very good example of how conversion of energies can help us to overcome our technical difficulties because had this energy conversion be not an option for us, it might have required us to set up a plant of 1500 MVA capacity which would have been of enormous size and highly unviable from an economic point of view. The obvious disadvantage of such a generator is that like conventional power generators it cannot provide a very large amount of power for long duration of time. In other words it stores energy in some form till some point of time and after that energy is released very quickly in an impulsive manner thus delivering large amount of power in a very short duration of time and hence becoming an ideal machine for short circuit testing of various electrical equipment.

VI. ACKNOWLEDGEMENT

Authors are thankful to the management of Central Power Research Institute, India for supporting this work.

REFERENCES

- [1] Datta A. K., Manisha Dubey, N. R. Mondal, B. V. Raghavaiah, "Motor-less operation of Short Circuit generator – A CPRI Perspective", International Conference on Electrical Power and Energy Systems (ICEPES-2010), pp.439-445, 26-28 August 2010 MANIT, Bhopal.
- [2] Arun Kumar Datta, N. R. Mondal, J. Santhosh, "Application of Static Frequency Converter on High Power Short Circuit Alternator–An Intelligent Step Towards Energy Efficiency Measure", IRF International Conference, pp.1-6, 27 Sept 2018, Pune, India.
- [3] Datta A. K., G. Venkateswarlu, M. A. Ansari, N. R. Mondal, "Excitation Control during Short Circuit Test Sequence of 1500 MVA Short Circuit Generator", International Conference on Advances in Computer, Electronics & Electrical Engineering (ICACEEE-2012), pp.207-211, 25-27 March 2012, Mumbai.
- [4] Arun Kumar Datta, "Modelling and simulation analysis of static drive for large synchronous machine", CIGRE Science & Engineering, pp.12-21, February 2016, France.
- [5] Arun Kumar Datta, N. R. Mondal, J. Santhosh, "Power Quality Study of 1500 MVA Motor-less Short Circuit Alternator", International Conference on Emerging Trends in Electronics, Electrical and Mechanical Engineering', organized by Technoarete International, pp. 50-54, 27th January, 2019, New Delhi.
- [6] Tsorng-Juu Liang, et al, "Analysis of 12 Pulse Phase Control AC/DC Converter", IEEE 1999 International Conference on Power Electronics and Drive Systems, PEDS'99, pp.779-783, July 1999, Hong Kong.
- [7] Manuals of 1500MVA short circuit generator (G2) in CPRI, Bhopal.



INNO SPACE
SJIF Scientific Journal Impact Factor
Impact Factor: 8.423



ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

9940 572 462 **6381 907 438** **ijirset@gmail.com**



www.ijirset.com

Scan to save the contact details