STM JOURNALS

International Journal of
Electrical Power and Machine Systems

Volume 2, Issue 2, 2024
July–December
DOI (Journal): 10.37591/IJEPMS

https://journals.stmjournals.com/ijepms

Research on Synchronous Generators AC Excitation Regulation Control System

Mansi Balram Handi[1,*], P.S. Chobe[1], D.B. Pardeshi[2]

Abstract

Based on various methods to supply excitation power to the synchronous generator, it is categorized into three different types of excitation systems for synchronous motors. The first one is the DC excitation system, the second is the AC excitation system and the third one is the static excitation system. The increasing size of contemporary power systems ensures system dependability and stability. A better supply of power is vital and has a big influence on improving people's quality of life and economic growth. The AC excitation system is the primary subject of this study. Variable rotor speed is one of the great features of an AC-excited generator; it enhances power system stability and permits deep operation without step loss. AC excitation generators have independent features for adjusting speed, reactive power, and effective power in addition to variable speed and constant frequency power. Maximum dependability, operating flexibility, and outstanding adjustment performance may be achieved with AC excitation generators by utilizing high-performance variable-frequency excitation power sources and suitable excitation control techniques. Synchronous generator functioning depends heavily on the excitation mechanism. The stability of the motor and power system is significantly increased by a well-designed excitation system, which also guarantees the generator's steady and dependable functioning.

Keywords: AC excitation system, stability, synchronous generator, regulation control system, generator

INTRODUCTION

History and Importance of this Research

Modern power systems are becoming increasingly larger, guaranteeing system stability and dependability. Superior electricity energy supply is extremely significant and has a major impact on improving people's living standards and economic development. In synchronous generators, the excitation control system is a critical component of power control and plays a significant role. In addition to maintaining a specific range of reactive power adjustment for a given generator terminal voltage, it can guarantee both dynamic and transient power operational stability. The development and optimization of generators and power systems are crucial.

*Author for Correspondence
Mansi Balram Handi
E-mail: mansihandi936@gmail.com

[1]Student, Department of Electrical Engineering, Sanjivani College of Engineering, Kopargoan, Ahmadnagar, Maharashtra, India
[2]Associate Professor, Department of Electrical Engineering, Sanjivani College of Engineering, Kopargoan, Ahmadnagar, Maharashtra, India

Received Date: October 31, 2024
Accepted Date: November 07, 2024
Published Date: November 20, 2024

Citation: Mansi Balram Handi, P.S. Chobe, D.B. Pardeshi. Research on Synchronous Generators AC Excitation Regulation Control System. International Journal of Electrical Power and Machine Systems. 2024; 2(2): 10–16p.

AC Excitation Generator Development Status

Domestic and International: Excellent working performance is a feature of many AC excitation generators. Appropriate excitation control methods can be selected during daily work to enhance the performance of a generator. As a result, many academics have studied and understood this aspect both in China and internationally. Research on AC excitation generators and other novel approaches to reactive power and power system stability issues was initiated as early as the 1950s in countries such as the US and Europe.

© STM Journals 2024. All Rights Reserved

As the name implies, dual-axis motors, or motors with two shafts, are the origin of studies on AC-excited generators. Academics are becoming increasingly interested in the applications of three-phase AC-stimulated rotors. With notable success, Japan acquired knowledge of AC excitation power production technology after 1980 and used it to pump energy storage power plants and flywheel energy storage power plants. In 1987 and 1993, two Japanese corporations joined two divisions. In 1990, two power plants collaborated to start one unit and create a high-power unit [1]. In Japan, three-phase AC excitation power production technology is continually being adopted by two power plants and one corporation. The scenario demonstrates how the variable-speed operation of the waterwheel increases its operational efficiency, strengthens the pump's ability to automatically adjust frequency during operation, and increases system stability by quickly adjusting the active and reactive power.

Numerous discussions on AC exciters and their systems have been conducted practically and experimentally in Western Europe and a few other countries. For instance, a French researcher developed a novel type of generator with variable speed and constant frequency, and MATLAB was used to run simulations to verify the design.

In the middle of the 1980s, domestic research on AC excitation generators was underway. A lengthy discussion was held by Chongqing University's electrical engineering major regarding the electromagnetic design application and principal data of d- and q-axis excitation asynchronous generators [2]. The control system of dual-axis excitation synchronous generators is taught and understood by Huazhong University of Technology instructors.

FUNDAMENTAL UNDERSTANDING AND DESIGN OF SYNCHRONOUS GENERATORS

Synchronous Generator's Basic Operating Principle

A motor's energy conversion is accomplished by the relative position of the charged conductor and magnetic field moving back and forth. Accordingly, a rotating motor is composed of two structural components: the rotor, which rotates, and the stator, which is the static component. The primary magnetic circuit of a synchronous motor is made up of an area known as the air gap between the rotor and stator. The ferromagnets that comprise the motor stator and rotor are made of air, and in synchronous motors, this gap serves as the primary magnetic path [3]. The excitation circuit is one of the main components of a synchronous motor circuit, and the coil that constitutes the circuit is known as the excitation winding. The excitation winding is connected to the direct current to generate the main magnetic flux because the ferromagnetic coil has relatively good magnetic conductivity. An excitation winding is typically installed on the rotor. An armature circuit is an example of an excitation winding that can sense the electromotive force on its coil. It is installed on the stator rather than on the rotor and is typically three-phase. Synchronous generators can be considered either electric motors or generators. When functioning as a generator, the motor additionally propels the rotor. The AC electromotive force arises when the armature conductor of the stator is obstructed by the magnetic field. A sinusoidal three-phase electromotive force manifests in the stator three-phase winding if the air-gap magnetic flux density is sinusoidal. The rotor speed (n) and motor number of pole pairs (p) determine the electromotive force frequency (f) of the alternating current. A motor with two poles experiences a periodic change in the electromotive force induced by the conductor when the rotor rotates once. A motor with opposite poles experiences p periodic changes in the electromotive force induced by the conductor if the rotor rotates once.

Fundamental Design of Synchronous Generators

The two components of a synchronous generator are the stator and the rotor. The stator is made up of a shell, iron core, coil, etc. Through the use of an induced electromotive force, the stator coil generates electrical energy; meanwhile, the iron core creates a magnetic circuit, and the shell offers protection.

The rotor coil is utilized for excitation, and it features an iron core and slip ring. The magnetic circuits and revolving shafts were provided by an iron core. The brush and slide ring were combined to create a static and dynamic pair. The excitation and output voltage regulation of the generator is handled by an excitation control component that is external to the rotor [4].

EXCITATION MECHANISM

Synchronous Generator's Technique of Stimulation

Differentiating the synchronous generator excitation system based on the output unit's excitation power source can result in three different types of excitation systems: DC, AC, and self-excited static. System of DC exciters: A unique DC generator within the generator is known as the DC exciter. The exciter and generator often share the same axis, and the excitation winding of the generator changes the location of the fixed brush on the main shaft to input DC from the exciter end.

AC Exciter System

Current travels to the rectifier after leaving the exciter. The generator rotor can be excited by the rectifier's ability to transform input AC power into DC power, which can then be transferred to the rotor. Separate excitation static excitation is another name for it because static rectification equipment is used.

System of Self-Excited Static Excitation

Self-excited static excitation is the process of generating excitation by converting power into the generator itself. The two types of self-excited static stimulation are self-compound excitation and self-parallel excitation.

Concept of Excitation System

A generator rotor consists of an iron core and a coil. The rotor coil must be activated to create a magnetic field. The excitation system provided a DC power source. Therefore, DC power must be supplied to the generator rotor for the excitation system to generate a revolving magnetic field. Because the stator can detect the electromotive force and the magnetic field moves in relation to it, the generator produces electricity.

Excitation System's Composition

The excitation system's composition included in the power section was the power supply and power rectifier (without rectifier). The generator rotor receives an appropriate excitation current from this crucial component of the excitation system. Select the primary circuit style and the device with the highest excitation system function based on the function of the power unit.

Regulator of Automatic Excitation

In the excitation system, the intelligent device is an automatic excitation regulator. Because it can regulate the entire excitation system, the performance of the automatic excitation regulator is crucial.

Automatic Adjustment Excitation Device

To enable comparison with the provided value, the transmitter is sent to the measurement unit for conversion when measuring signals, such as current and voltage. The amplifier increases the deviation that results from this comparison to help control the opening angle of the thyristor and, consequently, alter the magnitude of the excitation current.

The excitation control, protection, and signal loop comprise various components such as an auxiliary circuit, power transmitter, excitation suppression switch, fan within the cabinet, regulator failure, variable excitation overcurrent, and abnormal generator operating state. Demagnetization is required to swiftly lower the rotor magnetic field when synchronous generators experience related issues. Reducing the demagnetization time as much as possible without applying pressure on the rotor is the primary purpose of the demagnetization device. The methods of demagnetization can be linear or nonlinear depending on the specified excitation voltage.

© STM Journals 2024. All Rights Reserved

The Excitation Current Regulation Principle

The excitation current of a generator typically remains constant throughout the rotor circuit. The rotor circuit has very high and challenging current control. Changing the excitation current to alter the rotor current magnitude is a standard procedure.

Some of the frequently employed techniques are altering the thyristor's conduction angle, altering the extra excitation current of the excitation device, and altering the resistance of the excitation circuit. However, when the generator voltage, current, and power vary, the conduction angle of the thyristor rectifier will also be adjusted appropriately [5]. Changes in the conduction angle resulted in corresponding changes in the excitation current. Transistors and silicon-controlled electronic parts, which have the advantages of sensitivity, quick speed, fault-free area, large output power, compact size, and lightweight, often make up the assembly of this device. If a malfunction arises, it can quickly deexcite in addition to suppressing the generator's high voltage.

FUNDAMENTALS OF AC EXCITATION GENERATORS

AB-C Three-phase Coordinate System's Mathematical Depiction of an AC Excitation Generator

The construction of AC excitation generators is similar to that of three-phase winding motors, making it easier to understand AC excitation machines. A common assumption used while constructing the mathematical model of AC excitation generators is as follows:

1. When the generator lacked a dampening coil, it was equipped with two electrodes.
2. Magnetic circuit with negligible saturation, continuous self-inductance, and mutual inductance between coils.
3. The produced magnetoelectric potential was dispersed in a sinusoidal pattern around the perimeter of the air gap, and the three-phase windings differed from one another by 120° in space.
4. Carelessness in using iron cores.
5. Don't take temperature and frequency interference into account.

First, as indicated in Figure 1, the positive direction of the current, voltage, and flux chain was identified. The three-phase winding of the stator is a, b, c; the axis evenly splits 360° in space, with a difference of 120° between the two. Rotor winding shafts a, b, and c, such as the stator winding circumference, are 120° away from each other and rotate simultaneously with the revolving rotor, an axis, and there is an angle difference between the axes, assuming that corner, The angle may be altered,

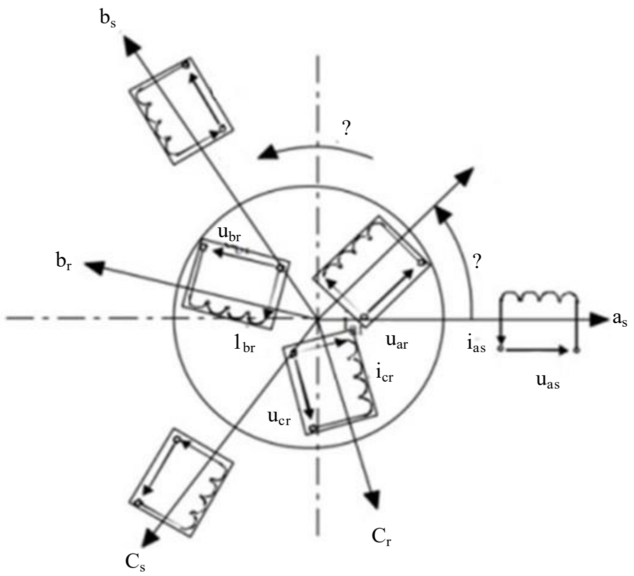

Figure 1. Electrical excitation generator physical model.

© STM Journals 2024. All Rights Reserved

and the positive direction of the winding axis of each phase becomes more essential and is chosen as the positive direction of the magnetic connection of each phase.

AC Excitation Generator Mathematical Model in the DQ-O Coordinate System

Aside from the A-B-C coordinate system with actual changes, the motor equation may also be expressed by fixed coordinate systems in space, coordinate systems with rotor motion, and constant synchronous rotation speed [6]. The operational characteristics of an AC exciter are as follows:

- The rotor speed may not be identical to the synchronous speed.
- The rotor speed has a composite magnetic electromotive force, and the rotor winding is most likely not zero above this speed.
- The angular rate of the rotor magnetic potential in space after the stator end linked to the power system is close to the angular frequency of the power grid and is almost steady.

As a result, in the D-Q-O coordinate, choose a variable that synchronizes with the speed; rotation is utilized to substitute the real variable in the A-B-C coordinates. In a stable condition, each electromagnetic quantity is merged into a space vector that is stationary relative to the coordinate axis and is a direct flow in the D-Q-O coordinate system. The equation form in an AC exciter is a nonlinear and time-varying coefficient differential equation, whereas in the D-Q-O coordinate system, it is a constant coefficient differential equation that includes other quantities such as current and magnetic flux links that exist in both DC and DC modes [7–12].

MODELLING AND OUTCOMES

Model of an AC Exciter Simulation

The model of an AC exciter simulation is shown in Figure 2. On the left side of the model, there is a speed-regulating system and an excitation system. The speed regulation system provides a steady output frequency of the voltage, and the output of the excitation system is the magnetic field voltage vfd (in pu), which is utilized to apply the Vf Simulink input to the Synchronous Machine module. The right-side features two three-phase parallel RLC loads, and the starting load power of the system is 500 kW. To analyze the system’s dynamic performance, a load power of 200 kW was provided and then removed using the circuit breaker module in the top-right corner. Additionally, the three-phase AC voltage and current were monitored using the B-SM module. This component is linked to the electrical terminal of the synchronous generator, and the output terminal of the synchronous generator outputs the rotor speed and AC excitation voltage [13].

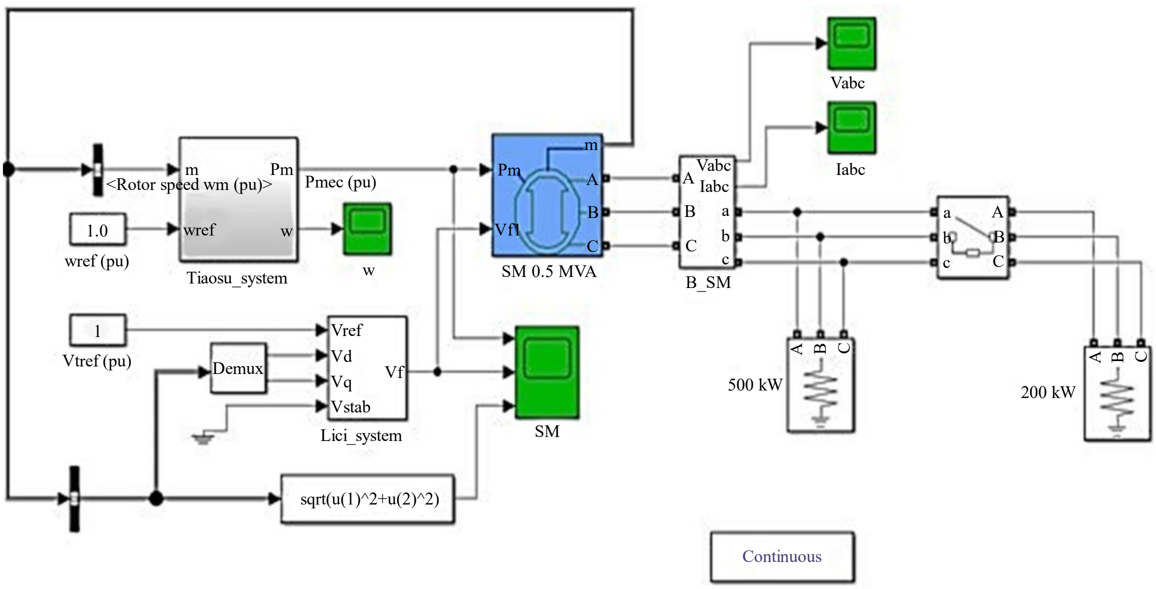

Figure 2. Model of an AC exciter simulation.

© STM Journals 2024. All Rights Reserved

The rotor speed is then transmitted back to the speed control and excitation system. The reference speed in the speed control system was set to one unit, with the rotor speed as the input and output mechanical power as the input of the synchronous motor. In the excitation system, the reference voltage was set as a unit, with vd and vq as inputs, and the output excitation voltage was utilized as the synchronous motor input [14].

AC Exciter Simulation Analysis

The output amplitude of the excitation voltage declines monotonically and eventually stabilizes, and the output voltage is unaltered. The output three-phase AC voltage remained constant. The amplitude of the output three-phase AC increased and remained constant.

It can be observed that by varying the size of the excitation current, variable-speed and fixed-frequency power production operation of the AC exciter can be achieved, and the stability of the power system can be enhanced.

CONCLUSION

In conclusion, this study highlights the critical role of excitation systems in ensuring the reliable operation of synchronous generators, particularly focusing on AC excitation systems. As power systems grow in size and complexity, the maintenance of system stability and dependability has become increasingly important. The AC excitation system, with its ability to adjust rotor speed, reactive power, and active power, offers significant advantages in terms of flexibility and performance. Its ability to operate at variable speeds without compromising stability makes it a valuable asset for modern power generation. Moreover, by utilizing high-performance variable-frequency excitation sources and advanced control techniques, AC excitation systems can provide enhanced reliability, improved system stability, and optimal performance under varying operational conditions. As power demand continues to rise, the adoption and refinement of AC excitation systems will play a pivotal role in improving both the efficiency and sustainability of power generation systems, ultimately contributing to economic growth and improved quality of life.

REFERENCES

1. Bhoi SL, Shantilal Salve S, Kumar DV, Pardeshi DB, William P. Deployment of slow power hybrid electric vehicle based on combustion engine. 3rd International Conference on Electronics and Sustainable Communication Systems (ICESC), Coimbatore, India. 2022. pp. 231–5. DOI: 10.1109/ICESC54411.2022.9885402.
2. Dhumane RA, Nikam TD, Hajare RN, Pardeshi DB, William P. Sustainable and intelligent control strategies for electric vehicle systems. 2nd International Conference on Edge Computing and Applications (ICECAA), Namakkal, India. 2023. pp. 1551–5. DOI: 10.1109/ICECAA58104.2023.10212140.
3. Dahatonde S, Jape N, Hajare RN, Pardeshi DB, William P. Arduino based vehicle overload detection system for prevention of accidents using ADC. 2023 5th International Conference on Inventive Research in Computing Applications (ICIRCA), Coimbatore, India. 2023. pp. 1633–6. DOI: 10.1109/ICIRCA57980.2023.10220821.
4. Roham MN, Kadam RS, Hajare R, Pardeshi DB, William P. Hybrid model for vehicle overload detection system using Arduino sensors. 2023 5th International Conference on Inventive Research in Computing Applications (ICIRCA), Coimbatore, India. 2023. p. 1431–4. DOI: 10.1109/ICIRCA57980.2023.10220870.
5. More AR, Shendkar OB, Pathak KG, Sanap PD, Pachore SN, William P. Survey on framework for governing modern cyber attacks in computer network. 2023 4th International Conference on Computation, Automation and Knowledge Management (ICCAKM), Dubai, United Arab Emirates. 2023. p. 1–6. DOI: 10.1109/ICCAKM58659.2023.10449582.
6. Nayak C, William P, Kumar R, Deepak A, Yadav K, Rao ALN, et al. Edge cloud server deployment with machine learning for 6G Internet of things. Int J Intell Syst Appl Eng. 2024;12:328–340.

© STM Journals 2024. All Rights Reserved

7. Hegde SK, William P, Basvant MS, Deepak A, Badhoutiya A, Rao ALN, et al. Energy-efficient bio-inspired hybrid deep learning model for network intrusion detection based on intelligent decision making. Int J Intell Syst Appl Eng. 2024;12:306–319.
8. Gow JA, Manning CD. Development of a photovoltaic array model for use in power-electronics simulation studies. IEE Proc Electric Power Appl. 1999;146:193–200. DOI: 10.1049/ip-epa:19990116.
9. Bellia H, Youcef R, Fatima M. A detailed modeling of photovoltaic module using MATLAB. NRIAG J Astron Geophys. 2014;3:53–61. DOI: 10.1016/j.nrjag.2014.04.001.
10. Yogeesh N, William P. Sensor-enabled biomedical decision support system using deep learning and fuzzy logic. In: Raza K, Barh D, Singh D, Ahmad N, editors. Advances in Ubiquitous Sensing Applications for Healthcare. Deep Learning Applications in Translational Bioinformatics. Vol. 15. Academic Press; 2024. p. 33–53. DOI: 10.1016/B978-0-443-22299-3.00003-7.
11. Warule AS, Barde VR, Barshile MK, Kambhire SV, Bibave RR, Pardeshi DB. Electric reaping and fertilizing machine. 5th International Conference on Inventive Research in Computing Applications (ICIRCA), Coimbatore, India. 2023. p. 1685–91. DOI: 10.1109/ICIRCA57980.2023.10220941.
12. Bibave R, Thokal P, Hajare R, Deulkar A, William P, Chandan AT. A comparative analysis of single phase to three phase power converter for input current THD reduction. 2022 International Conference on Electronics and Renewable Systems (ICEARS), Tuticorin, India. 2022. p. 325–30. DOI: 10.1109/ICEARS53579.2022.9752161.
13. Bibave R, Kulkarni V. A novel maximum power point tracking method for wind energy conversion system: A review. 2018 International Conference on Computation of Power, Energy, Information and Communication (ICCPEIC), Chennai, India. 2018. p. 430–3. DOI: 10.1109/ICCPEIC.2018.8525198.
14. Bibave R, Kulkarni V. Maximum power extraction from wind energy system by using perturbation and observation method. 2018 International Conference on Smart Electric Drives and Power System (ICSEDPS), Nagpur, India. 2018. p. 105–10. DOI: 10.1109/ICSEDPS.2018.8536033.

© STM Journals 2024. All Rights Reserved