ISSN 2277-2685
IJESR/Jan-Mar. 2026/ Vol-16/Issue-1/249-255
Afra Begum *et. al.,* / International Journal of Engineering & Science Research

Excitation System of Hydro Power Generator

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Abstract
In modern hydroelectric power plants, synchronous generators are commonly used due to their ability to deliver stable and efficient electrical power. For proper operation of a synchronous generator, an excitation system is essential as it supplies direct current to the rotor winding. In high-capacity hydroelectric generating units, such as 40 MW generators, a large and reliable excitation system is required to maintain voltage stability and system performance under varying load conditions.
The Lower Jurala Hydroelectric Power Plant consists of six generating units, each having a capacity of 40 MW. Due to the large rating of these generators, the excitation system must be robust and capable of providing sufficient field current. A secure and well-designed excitation system ensures smooth generator operation, improves system reliability, and enables the generator to withstand abnormal operating conditions and electrical disturbances. To protect the generator and excitation system from abnormal operating conditions, various protection schemes are provided such as voltage protection, stator current protection, over-excitation and under-excitation protection, and digital control protections. Each unit is equipped with an Automatic Voltage Regulator (AVR) and Field Current Regulator (FCR) for controlling terminal voltage and excitation current. In digital excitation systems, a small error margin known as droop, typically ranging from 0% to 5%, is maintained to ensure continuous relay operation and system stability. Since the excitation system handles high currents, it is prone to temperature rise during operation. Therefore, adequate heat sinks and cooling systems are provided to dissipate heat effectively, ensuring reliable performance and long service life of the excitation system. It also reduces maintenance requirements and improves overall system availability.

Keywords: *Automatic Voltage Regulator (AVR); Excitation System; Field Current Regulator (FCR); Hydroelectric Power Plant; Synchronous Generator; Thermal Management; Voltage Stability; 40 MW Generator.*

INTRODUCTION

Lower Jurala Hydro Electric Project, it is located in Wanaparthy district of Telangana State. It has a total of 6 generators each having a generating capacity of 40MW. This plant is different from other in many ways like a new canal has been dug to place this plant and water has been diverted.

The generators are Tube type power generators which are very rarely used in India a part of generated power is used for the operation, control and generator excitation of the plant. A complete digitalized control system is given to it. It has a unique property of back charging ability of 1,3,5 units in which the equipment except generator is used for the operation of the plant when there is no generation in the plant which is used for lighting control etc.

The 6 units are connected to 2 bus bars provided with isolators and circuit breakers for flexibility of using any units. These bus bars are connected to 4 feeders. It is given with PLCC technology for communication with other power plants and substations for load variation and fault indication. Tube type power generators are very rear in India which can actually work at low head and greater power output. Lower Jurala is one of its kind. Various protection systems are employed in this plant so that any complication can be faced readily so that damage of the high cost instruments and equipment's can be minimized to a large extent.

Two DC power banks are installed to operate the control systems at no back charging and generation to initialize the auxiliary transformers, oil pumps, water pumps, guide vanes etc... One power bank is located near Main control room and the other is located at the Switch yard.

LITERATURE SURVEY

Md. Rishad Hossain presents a study on synchronous generator stabilization using a thyristor-controlled supercapacitor energy storage system. The work focuses on improving the dynamic stability of power systems by integrating energy storage with excitation control. The proposed system utilizes thyristor-based control to regulate the charge and discharge of the supercapacitor, thereby enhancing transient response and reducing oscillations in generator output. The study demonstrates that the combination of excitation control and energy storage provides better voltage stability and improves overall system performance under varying load conditions [1].

Vladimir presents an optimization study of excitation system parameters for the Kegums hydro power plant in Latvia. The research emphasizes the importance of proper tuning of excitation system parameters to achieve optimal generator performance and stability. By analyzing system behavior under different operating conditions, the study identifies key parameters that influence voltage regulation and system response. The results show that optimized excitation control significantly improves the efficiency and reliability of hydroelectric power generation systems [2].

OBJECTIVE

To study the excitation system of a hydroelectric generator and understand its role in controlling generator voltage. To analyze the working of key components such as the AVR, excitation transformer, and thyristor rectifier used in the generator excitation system.

EXCITATION SYSTEM

The purpose of the excitation system is to control the stator voltage of the generator. The present excitation system is of the static type. Excitation control is based on a digital automatic voltage regulator (AVR), which controls the firing of thyristor bridges so as to supply the generator with variable field current. The equipment can be configured according to the requirements of the control system. There are several possible configurations (two redundant channels, automatic/manual mode...) and the number of rectifier bridges depends on the field current to be supplied to the generator. The excitation system can be connected to a DCS system via a field bus (MODBUS or E8000). The excitation system hardware is housed in a sturdy and compact cubicle. The regulator design avoids any wiring faults and ensures good EMC performance.

There are 3 parts in excitation system of Power plant they are:

1. Excitation Transformer

The excitation transformer steps down the generator voltage to a suitable level for the excitation system. It supplies controlled AC power to the rectifier and AVR for field excitation.

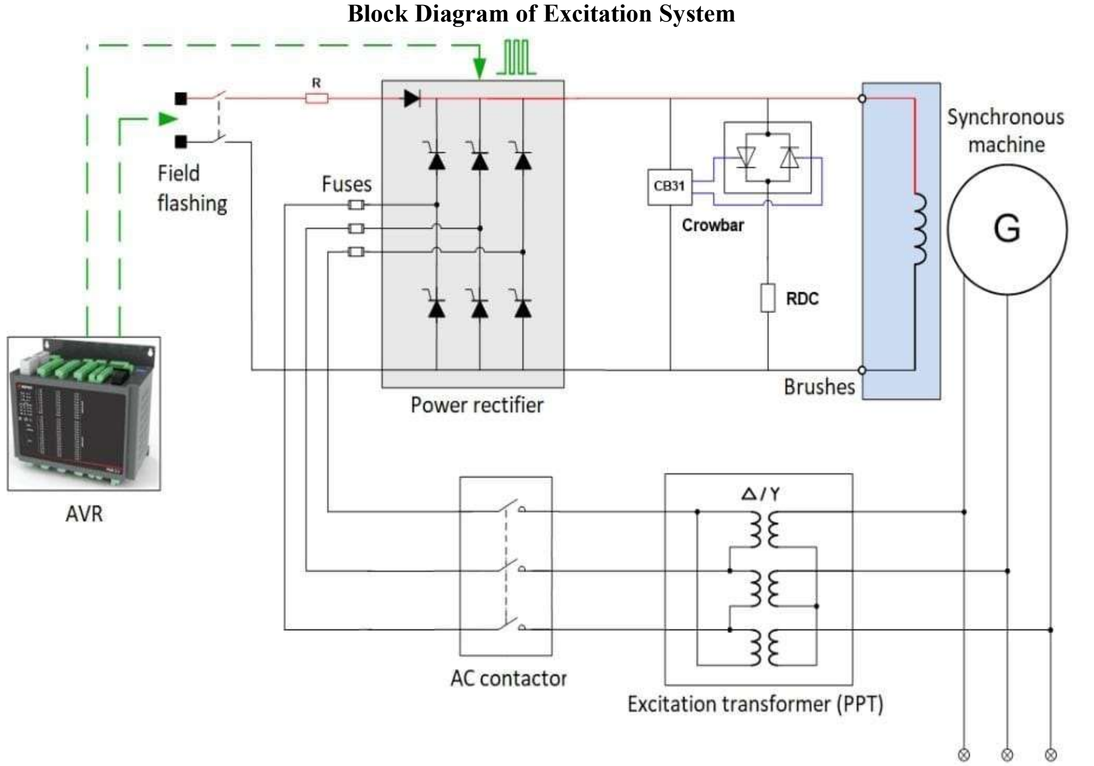
2. Regulation System

The regulation system (AVR) controls the generator voltage by adjusting the field current automatically. It continuously monitors terminal voltage and maintains it constant under varying load conditions.

3. Thyristor Rectifier

The thyristor rectifier converts AC supply into controlled DC for the rotor field winding. It regulates the amount of DC current based on AVR signals to control excitation.

Block Diagram of Excitation System



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Regulation System

Basic AVR/FCR configuration

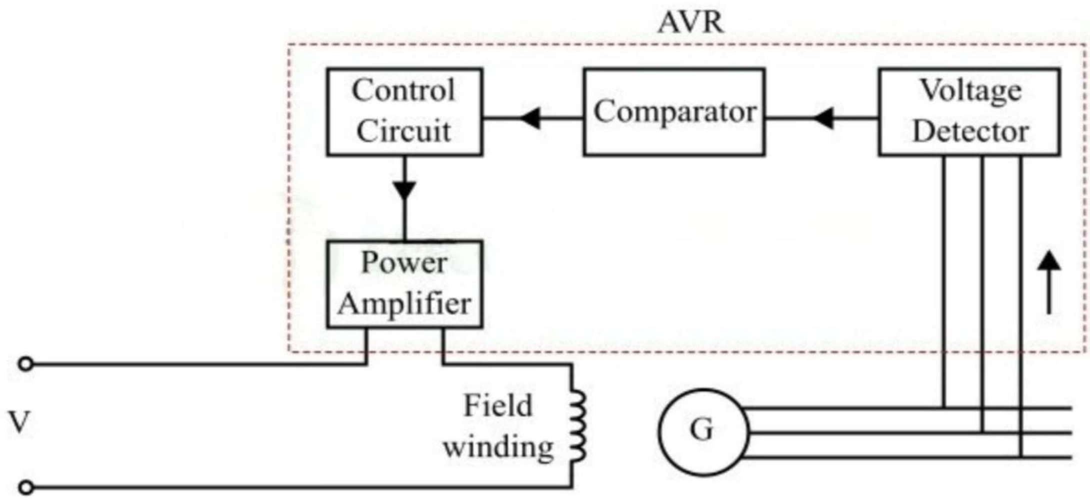
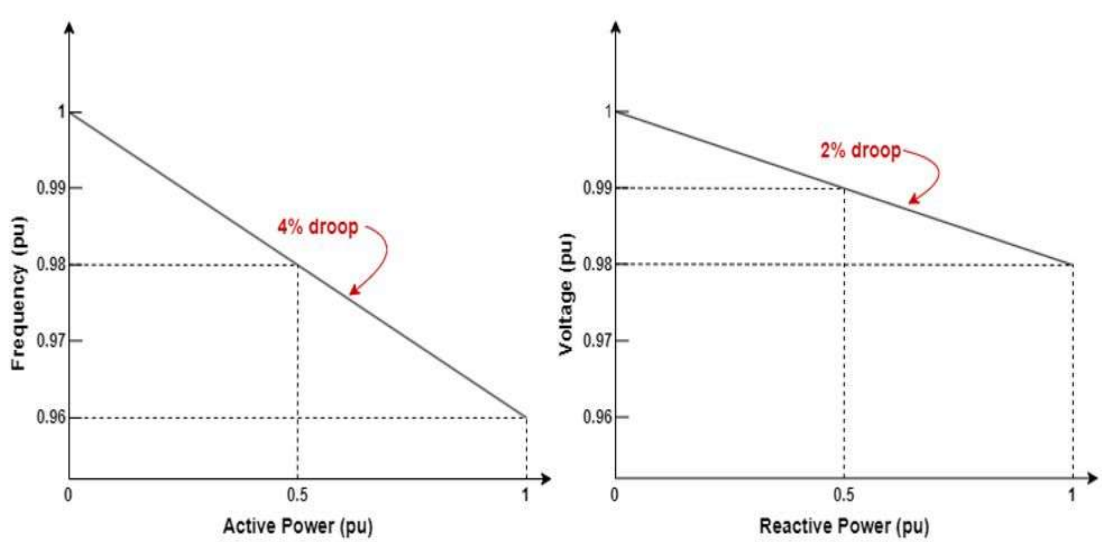


fig 1 AVR configuration

The Automatic Voltage Regulator (AVR) controls the generator output voltage so as to improve the, generator's operational stability and keep it within its working limits. The AVR is a digital type and the regulation loops are processed by a CPU board. Several specific boards are connected to the main CPU board to perform electrical Input/ Output functions (both logic and analogue). The input/output boards are linked to terminal plates (for user connections) by means of ribbon cables connected in front of the I/O boards. LEDs in front of the electronics boards indicate the status of the board itself. The system consists of one automatic voltage regulator with an integrated digital field current regulator

The manual mode is used for testing purposes or in case of malfunction of the generator voltage measuring system. In the latter case, the system changes automatically from the automatic mode to the manual mode. A tracking facility allows a smooth transfer from one mode to the other. The system consists of two identical digital voltage regulators, Regulator 1 and Regulator 2, both with an integrated FCR (Field Current Regulator). Each regulators its own power supply and its own digital thruster firing module.A failure of the active regulator causes the system to change over to the stand-by regulator. A tracking function allows a smooth transfer from one regulator to the other.

Droop characteristics



Protection

Over Voltage Protection by Crowbar

This function connects a set of resistors to the rotor windings, in order to rapidly reduce the generator excitation current in case of overvoltage caused by a short-circuit across the terminals of the generator. Since the overvoltage can be positive or negative, this protection is performed by means of two thyristors connected top to bottom. The voltage regulator includes no circuit for thyristor control; this is performed by a special electronic board without any external power supply. When the crowbar is used, the thyristor bridges of the excitation system are forced to inverter mode.

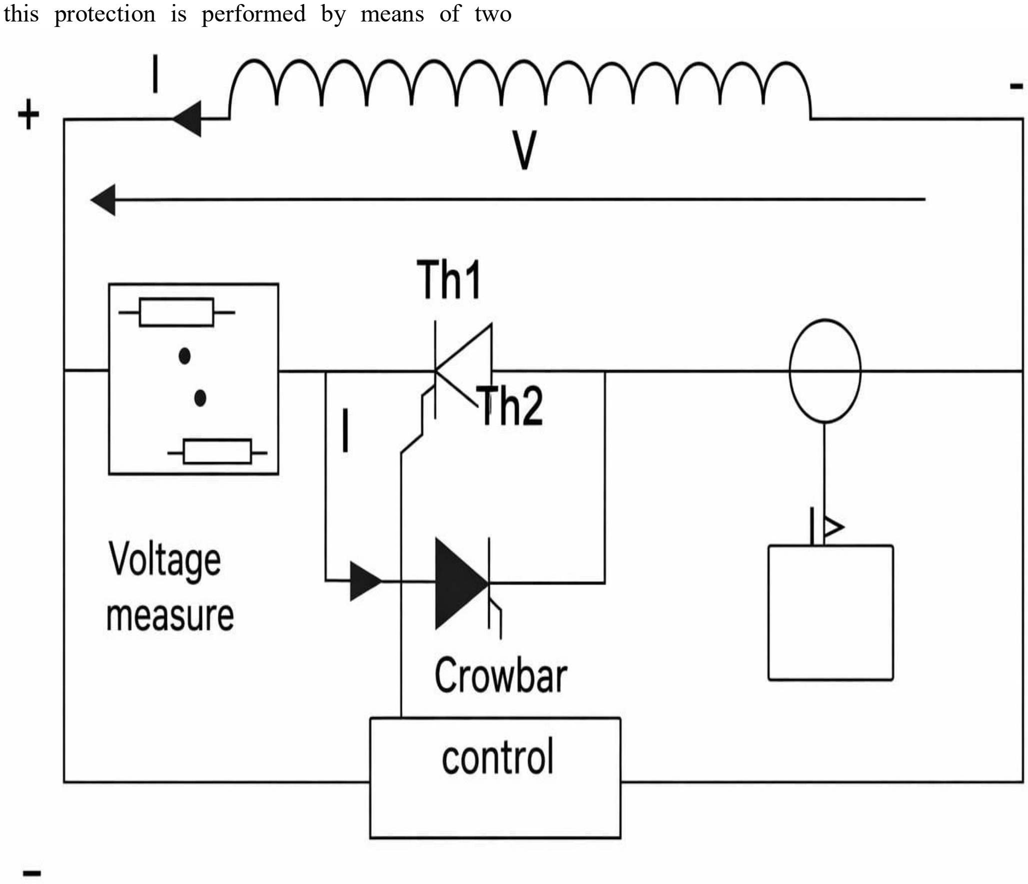


Fig 3 Crowbar protection Circuit

In case of a positive overvoltage, thyristor Th2 forward biased and the overvoltage is attenuated through a resistor network. A current relay detects a current in the crowbar circuit and gives a tripping order to the excitation system. Once the crowbar is activated, the Automatic Voltage Regulator (AVR) temporarily loses control over excitation. The system then shifts into a protective mode, and normal regulation is restored only after the fault condition is cleared and the system is reset.

Modern systems also include coordination between the crowbar circuit and other protection schemes such as overvoltage relays, differential protection, and stator protection. This coordination avoids unnecessary operation and ensures selective tripping.

Finally, proper isolation and interlocking mechanisms are incorporated so that the crowbar circuit does not operate during normal transient conditions like load changes or synchronization, thereby improving reliability and avoiding false triggering.

Protection against negative overvoltage

In case of reverse power from the generator field winding, thyristor Th1 is forward biased and the energy of the winding is discharged through Th1 and the discharging resistors. A current relay detects a current in the crowbar circuit and gives a tripping overvoltage excitation system.

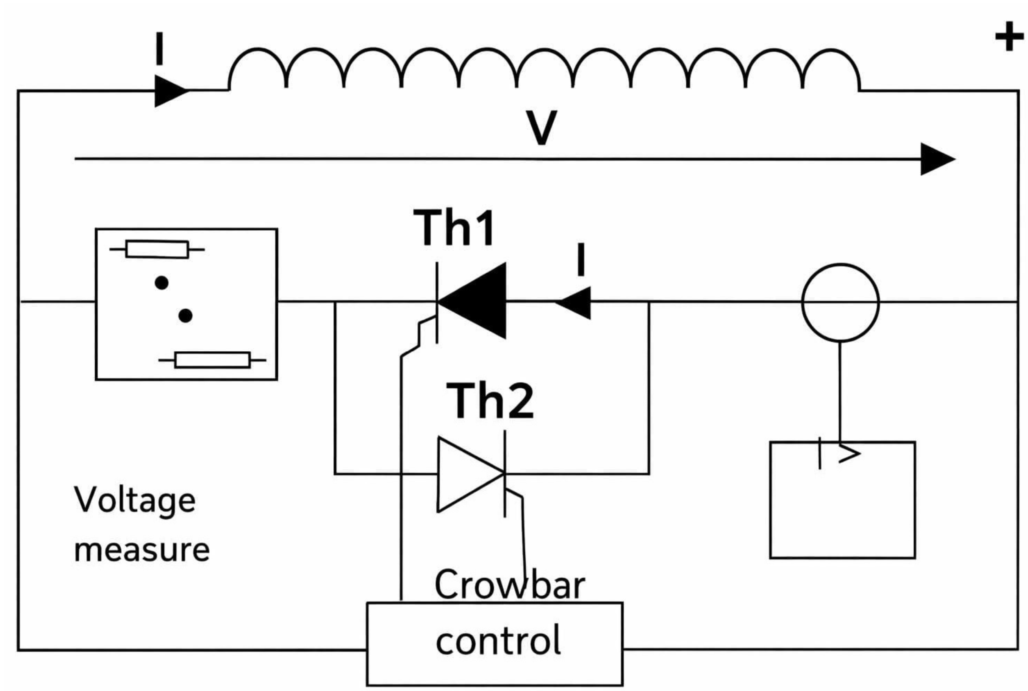


Fig 4 Negative Overvoltage protection circuit

Overvoltage protection by non-linear resistors

In small and medium sized generators, overvoltage protection can also be carried out by a set of non-linear resistors (RNL). These resistors, connected in parallel with the rotor circuit, are designed to limit the overvoltage to 75% of the dielectric insulation test voltage of the rotor.

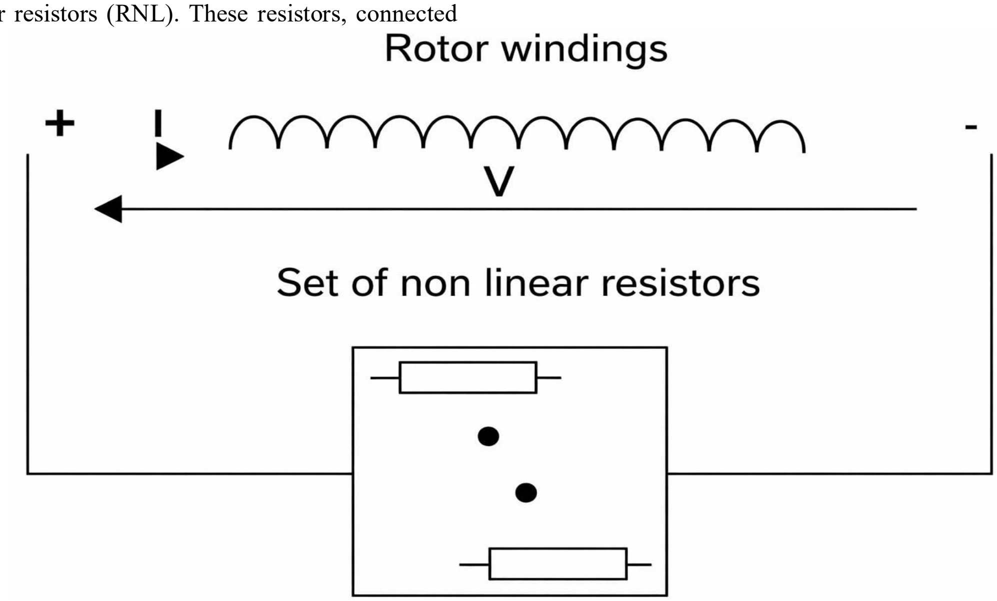


Fig 5 Nonlinear resistors protection circuit

Discharge of the field windings

When the field breaker is opened, the current in the windings is discharged through a set of linear resistors. These resistors are connected by means of an auxiliary NC contact of the field breaker, which is closed 1 to 3 ms before the opening of the main contacts (NO). The number of resistors depends on the energy to be discharged and their values are calculated such as to limit the peak voltage to a value less than the maximum rupturing voltage of the field breaker. By default, the discharging resistors are linear, but they can also be of the non-linear type if short discharging times are required.

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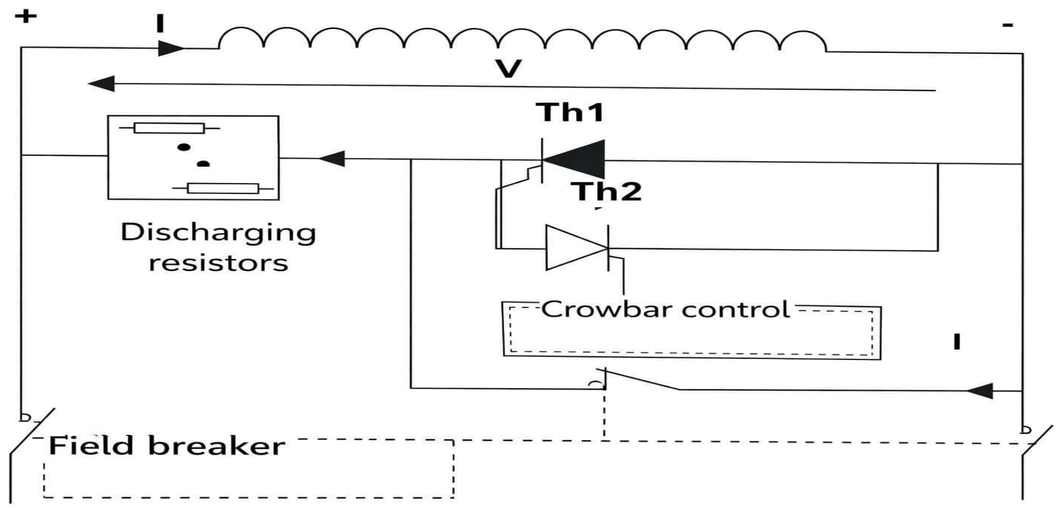

Fig 6 Discharge of field windings circuit

Surge and Lightning protection:

Surge and lightning protection in the excitation system is essential to protect electrical equipment from high voltage transients caused by lightning strikes or switching operations. These sudden surges can damage sensitive components such as the Automatic Voltage Regulator (AVR), rectifier units, and field windings of the generator. To prevent this, lightning arresters and surge protection devices are installed, which provide a low-resistance path for excess voltage to safely discharge into the ground. This protection helps in preventing insulation failure, equipment damage, and ensures the continuous and reliable operation of the excitation system.

Fig 7 Lightning arrestors

Conclusion And Future Scope

Conclusion

The study of the excitation system of power generators, particularly the thyristor rectifier used in hydroelectric power plants like Lower Jurala, highlights its critical role in maintaining stable and reliable power generation. The thyristor rectifier efficiently converts AC power into controlled DC supply for the generator field winding, enabling precise control of excitation and ensuring constant terminal voltage under varying load conditions. The coordination between the Automatic Voltage Regulator (AVR) and the rectifier provides fast dynamic response, improved system stability, and protection against voltage fluctuations. Through this project and plant visit, a clear understanding of both theoretical concepts and practical implementation has been achieved, demonstrating that the excitation system is essential for the efficient, safe, and continuous operation of hydroelectric generators.

Future Scope

The future of excitation systems in power generators is expected to advance significantly with the development of modern power electronics and intelligent control technologies. Innovations such as digital and microprocessor-based AVRs, artificial intelligence-driven control systems, and the use of advanced semiconductor devices like IGBTs can enhance the performance, efficiency, and response time of excitation systems. Additionally, the adoption of predictive maintenance using real-time monitoring and data analytics can reduce failures and improve reliability. With the growing integration of renewable energy sources and the need for smarter grids, future excitation systems will become more adaptive, automated, and robust, ensuring better voltage control, grid stability, and sustainable power generation.

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