BRUSHLESS EXCITATION SYSTEM

A MINI PROJECT REPORT

submitted to

JAWAHARLAL NEHRU TECHONOGICAL UNIVERSITY

Submitted in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

in

ELECTRICAL AND ELECTRONICS ENGINEERING

by

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CERTIFICATE

This is to certify that the project report entitled "**BRUSHLESS EXCITATION SYSTEM**" submitted by **THOTAMALLA RAVI, SHARMILI PALLI & SHRAVAN MADHAVAN** to the Jawaharlal Nehru Technology University, Hyderabad, Andhra Pradesh in partial fulfillment for the award of Degree of Bachelor of Technology in Electrical and Electronics Engineering is a record of bonafide work carried out by them under my supervision from 24/6/2013 to 8/7/2013 in BHEL, Ramachandrapuram-32.

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CERTIFICATE

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In our present project we have chosen the topic- "BRUSHLESS EXCITATION SYSTEM". This technology is manufactured and processed in BHEL. Synchronous generator or motor requires DC current in rotor. Conventional way of providing DC supply is by using commutators, which requires heavy maintenance. To overcome this we install BRUSHLESS EXCITATION systems. This is an advanced modern technology manufactured at BHEL.

ABSTRACT

The brush gear and slip-ring have become such a vital part that requires high maintenance and are source of failures, thus forming weak links in the system. With the advent of mechanically robust silicon diode capable of converting AC to DC at a high power level, the usage of brush gear and slip ring have reduced considerably.

This project emphasizes brushless excitation system which overcomes these faults and has become popular and being employed. The field excitation is provided by a standard brushless excitation system which consists of rotating armature diode, diode bridge and stationary field.

The proposed system captures important characteristics of alternator that include excitation of alternator as well as voltage control method. Brushless excitation system consists of one pilot exciter – DC generator with rotating PM as the field and the armature as the stator. The armature of the pilot exciter is connected to the stator of the main exciter which is a 3-Φ synchronous generator. The rotor of the main exciter is connected to a diode bridge to get DC.

Fig. (i). A brushless DC excitation system

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BHEL PROFILE

Established more than 40 years ago, BHEL is the largest engineering and manufacturing enterprise of India in the energy & infrastructure related sectors. BHEL is amongst world's rarest few who have the capability to manufacture entire range of power plant equipment. Since its inception, BHEL is maintaining a consistent track record of growth, performance and profitability.

The company has grown in stature over the years with continued inflow of orders, manufacturing prowess, continued thrust on technology leading to a strong presence in domestic and international markets as a major supplier of power plant equipment besides establishing substantial inroads in select segment of products in Industrial sector and Railways.
The company has realized the capability to deliver 15,000 MW p.a. power equipment capacities and the further expansion program is underway to reach 20,000 MW p.a by 2012.

BHEL caters to core sectors of the Indian Economy viz., Power Generation and Transmission, Industry, Transportation, Renewable Energy, Defense, etc. The wide network of BHEL's 15 manufacturing divisions, 2 repair units, 4 power sector regions, 8 service centers, 15 regional offices, 2 subsidiaries and a large number of Project Sites spread all over India and abroad enables the company to provide most suitable products, systems and services- efficiently and at competitive prices. The company has entered into a number of strategic joint ventures in supercritical coal fired power plants to leverage equipment sales besides living up to the commitment for green energy initiatives.

BHEL, where Quality Systems as per ISO-9000 have taken deep roots, has now made significant achievements in Business Excellence by securing recognition certificates from CII for four out of five units that participated in the CII-EXIM Business Excellence Award scheme in 2010-11. Continuing its tradition of bagging prestigious national/international awards, the company has been honored with several awards which included "EEPC Star Performer Award" in the Product Group of Project Exports for 20th consecutive year; SCOPE Award for Excellence and Outstanding Contribution to the Public.

Sector Management; "Dainik Bhaskar India Pride Award:2010" in Heavy Industries Category; "ICWAI National Awards for Excellence in Cost Management" for 2009 among public and private sector companies for the fifth successive year; "India Power Award for Equipment Manufacturing and for electrifying Lakshadweep Islands with Solar Power" from Council of Power Utilities; Six Prime Minister's Shram Awards including one "Shram Bhushan" and three "Vishwakarma Rashtriya Puraskars"; "IEI Industry Excellence Award 2010" for Overall Business Excellence and Industry Practices from the Institution of Engineers (India); "NDTV Profit Business Leadership Award 2010".

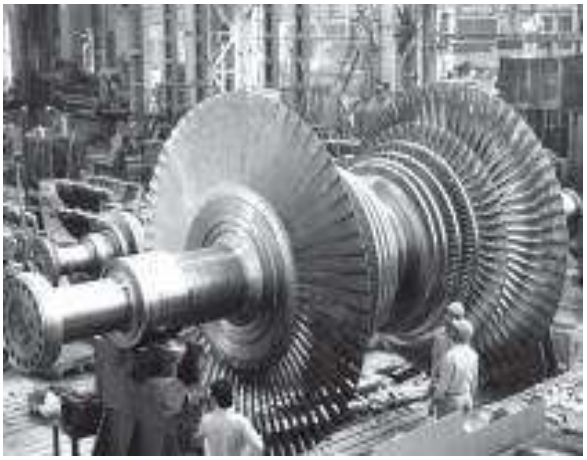

Fig. (i) 500 MW Turbine LP Rotor Assembly at BHEL plant

Power Generation

In Power generation segment, BHEL is the largest manufacturer in India supplying wide range of products & systems for thermal, nuclear, gas and hydro-based utility and captive power plants. BHEL has proven turnkey capabilities for executing power projects from concept-to-commissioning. BHEL supplied utility power generating sets have crossed the landmark of 1, 00,000 MW and continue to maintain the record of nearly two-third of the overall installed capacity and around three-fourth of the power generated in India. BHEL supplies steam turbines, generators, boilers and matching auxiliaries up to 800 MW ratings, including sets of 660/700/800 MW based on supercritical technology. BHEL has facilities to go up to 1000 MW unit size. To make efficient use of high ash content coal available in India, BHEL also supplies circulating fluidized bed combustion (CFBC) boilers for thermal plants. BHEL is the only Indian company capable of manufacturing large-size gas-based power plant equipment, comprising of advanced-class gas turbines up to 289 MW (ISO) rating for open and combined-cycle operations. BHEL engineers and manufactures custom-built hydro power equipment.

Its range covers turbines of Francis, Pelton and Kaplan runners, pump turbines, bulb turbines and mini-micro hydro plants, with matching generators, for different head-discharge combinations.

Fig. (ii). Dadri 490 MW unit commissioned in 2010-11

BHEL is one of the few companies worldwide, involved in the development of Integrated Gasification Combined Cycle (IGCC) technology which would usher in clean coal technology.

Industries

BHEL is a leading manufacturer of a variety of Industrial Systems & Products to meet the demand of a number of industries, like metallurgical, mining, cement, paper, fertilizers, refineries & petro-chemicals etc. besides captive/industrial power utilities. BHEL has supplied systems and individual products including a large number of co-generation Captive power plants, Centrifugal compressors, Drive Turbines, Industrial boilers and auxiliaries, Waste heat recovery boilers, Gas turbines, Pumps, Heat exchangers, Electrical machines, Valves, Heavy castings and forgings, Electrostatic precipitators, ID/FD fans, Seamless steel tubes etc. to a number of industries other than power utilities.

BHEL has also emerged as a major supplier of controls and instrumentation systems, especially distributed digital control systems for various power plants and industries. The Industry business sector of the company is fully geared to execute EPC contracts for captive power plants from concept to commissioning utilities. BHEL has also emerged as a major supplier of controls and instrumentation systems, especially distributed digital control systems for various power plants and industries. The Industry business sector of the company is fully geared to execute EPC contracts for captive power plants from concept to commissioning.

Fig. (iii) 4X120 MW & 1X67 MW Tata Captive Power Plant at Jojobera, Jharkhand

Transportation

Most of the trains of Indian Railways, whether electric or diesel powered, are equipped with BHEL's traction propulsion system and controls. The systems supplied are both with the conventional DC and state-of-the-art AC drives. India's first underground metro at Kolkata runs on drives and controls supplied by BHEL. Almost all the EMUs in service are equipped with electrics manufactured and supplied by BHEL. BHEL has proved once again its capabilities and technological excellence by successfully establishing itself as an indigenous manufacturer of energy efficient IGBT based propulsion system for AC drives, a landmark achievement in transportation sector. BHEL has also diversified into the area of track maintenance machines and coach building for Indian Railways and undertakes retrofitting and overhauling of rolling stock.

Loco manufacturing capacity at Jhansi unit is under augmentation to meet increased requirements of Indian Railways.

Fig. (iv) Electric Locomotive (25 KV AC, type WAG 7)

Renewable Energy

In conformity with its concern for the environment, BHEL has been contributing to the national effort for developing and promoting renewable energy based products on a sustained basis. Starting from small applications like Solar Powered Street Lighting, Rural Water Pumping Systems, Railway signaling, Offshore Drilling Platforms, etc., BHEL has supplied and commissioned large size stand-alone as well as Grid-interactive Solar Power Plants in a number of major cities and remote areas of the country. With an aim to perform a significant role in National Solar Mission's proposed target of 20,000 MW of grid connected solar power, BHEL signed an agreement with Abengoa, Spain, a leader in solar projects to provide EPC solutions in Concentrated Solar Thermal Power (CSP) areas.

Oil and Gas

BHEL possesses expertise to design, manufacture and service various types of onshore rigs to suit the Indian service conditions. The range of equipment covers onshore deep drilling rigs, super-deep drilling rigs, heli-rigs, work-over rigs, mobile rigs and desert rigs with matching draw works and hoisting equipment. BHEL now has the capability to manufacture conventional on shore deep drilling rigs up to a depth of 9,000 meters, mobile rigs to a depth of 3,000 meters and well servicing rigs to a well depth of 6,100 meters. The company is in the process of manufacturing environment friendly AC-technology based oil rings for on shore application.

BHEL is supplying onshore drilling rig equipment viz. Draw works, Rotary-table, Traveling block, Swivel, Mast and Sub structure, Mud systems and Rig electrics, Well heads & X-Mas tree valves up to 10,000 psi rating for onshore as well as offshore application to ONGC, Oil India Ltd. and Private Drilling Companies.

Fig. (v) SPV Power Plant

Transmission

BHEL has significant presence in the field of power transmission in India with a wide range of transmission systems and products. The products manufactured by BHEL include Power transformers, Instrument transformers, Dry type transformers, Shunt reactors, Vacuum and SF6 switchgear, Gas insulated switchgears, Ceramic insulators, etc. Major critical hardware such as capacitor banks, circuit breakers, control and protection equipment and thyristor valves are in its manufacturing range.

BHEL has emerged as the first company in India to indigenously develop and manufacture 333 MVA, 1200 kV transformer. BHEL has also manufactured 1200 kV CVT for transmission test station of PGCIL at Bina and 530 kN disc insulators for 1200 kV UHVAC transmission lines. Notably, BHEL has received the breakthrough order for world's first +/- 800 KV 6,000MW Ultra High Voltage Multi-Terminal DC Transmission Link between North-east and Agra from Power Grid Corporation of India Ltd.

BHEL has developed and commissioned indigenous 36 kV and 145 kV Gas Insulated Substations (GIS). The company is now developing 33 KV double bus design to meet the transmission requirements. The company has emerged as the only indigenous manufacturer of largest rating (5 MVA) Dry Type Transformers.

The Company accepts full project responsibility for feasibility / system studies, execution and commissioning of Fixed Series Compensation / Controlled Shunt Reactor schemes. BHEL has the expertise and extensive on-the job exposure for design and applications relating to Power System Studies and Feasibility Studies etc.

Fig. (vi) 400 KV Substation Execution by BHEL for PGCIL

International Business

In international arena, the prevailing environment of heightened uncertainties worsened by political turmoil in the Arab world has adversely affected the business prospects of BHEL's traditional markets. In spite of such situation, BHEL was able to sustain its exports momentum and expanded its foot print in new markets. The company is poised to maintain its references in the overseas market encompassing almost the entire range of products and services, covering Thermal, Hydro and Gas-based turnkey power projects, Substation projects, Rehabilitation projects, besides a wide

variety of products like Transformers, Motors, Compressors, Valves, Electrostatic Precipitators, Photovoltaic equipments, Insulators, Heat Exchangers, Switchgears etc.

The company has been successful in meeting the requirements of international markets in terms of complexity of work as well as technology, quality and other requirements. BHEL has proved its capability to undertake projects on fast-track basis. Continued focus on After-Sales-Services led to orders for Spares & Services from UAE, Bangladesh, Nepal, France, Sri Lanka, Kazakhstan, Iraq, New Zealand, Malta, Thailand, Yemen and Libya. Besides undertaking turnkey projects on its own, BHEL also possesses the requisite flexibility to interface and complement other international companies for large projects, and has also exhibited adaptability by manufacturing and supplying intermediate products.
The company is taking a number of strategic business initiatives to fuel further growth in international business which includes exploration of opportunities in solar energy related projects, equipments and projects in Transmission & Distribution arena in overseas markets.

Fig. (vi) 300 MW Western Mountain Extension Project for GECOL, Libya

Technology Upgradation, Research & Development

BHEL's products and systems are technology intensive and R&D/technology development is of strategic importance in its endeavor to become an all-inclusive engineering enterprise. During the year, BHEL has invested R 982 Cr. on R&D efforts which are 18 % higher than previous year. A turnover of R 7809 Cr. was achieved through products and systems developed in-house, an increase of 23% over the previous year. A total of 91 patents and copyrights were granted during the year enhancing the intellectual capital to 1,438 patents & copyrights.
Significantly, BHEL was ranked as the number one company in terms of filing patents and second highest investor in R&D in India by Economic Times Intelligence Group. The company won the coveted CII-Thompson Reuters Innovation Award-2010 in the "Hi Tech Corporate" category in recognition of its innovation and entrepreneurship in India.

Fig. (vii) Sh. Praful Patel, Hon'ble Union Minister of HI & PE inaugurating the new state-of-the-art Electric Machines Shop at BHEL, Bhopal

In conformity with engineering and technology objective, the Corporate R&D Division at Hyderabad leads BHEL's research efforts using emerging technologies to offer State-of-the-art total engineering solutions. Research and product development centers at each of the manufacturing divisions play a complementary role. Centers of excellence have been set up for Simulators, Computational Fluid Dynamics, Permanent Magnet Machines, Surface Engineering, Intelligent Machines and Robotics and Machine Dynamics. As the Seventh in the series, BHEL has established a Centre of Excellence for Compressors & Pumps Dynamics.
Initiatives for setting up of a new Centre of excellence for Nano-technology at Hyderabad are underway. "R&D Advisory Council" has been formed with eminent scientists and dignitaries from Govt. of India to advise BHEL on R&D strategies for growth and to enable it face the new challenges in the market.

In addition to the Corporate R&D Division, BHEL has four specialized institutes, viz., Welding Research Institute at Trichy, Ceramic Technological Institute at Bangalore, Centre for Electric Traction and Hydro lab at Bhopal and Pollution Control Research Institute at Haridwar.

Fig. (ix) 180 MVA, 1200 KV Testing Transformer & 80 MVAR, 765 KV single phase Shunt Reactor at UHV lab, Bhopal

Human Resource Development Institute

Guided by the HRD Mission statement 'To promote and inculcate a value-based culture utilizing the fullest potential of Human Resources for achieving the BHEL Mission", the HRDI through a step by step strategic long term training process and several short term need based programmes based on comprehensive organizational research, enables the human resources to unearth and hone their potential.

In a major advancement, an integrated Human Resource Management system was implemented during the year 2010-11, which aims at reaching out to the internal stakeholders on real time basis and redefining the role of HR functions as a strategic partner in business, through process standardization, optimization and seamless enterprise integration.

Some of the Core programmes include Strategic need based programmes; Competency based programmes and Functional programmes like Advanced Management Programmes, General Management Programmes, Strategic Management Programmes, Senior Management Programmes, Middle Management Programmes, Young Managers Programmes and self-starter programmes for budding managers.

In addition, the HRDI provides professional support to Corporate HR and HRDCs at Units/Divisions. HRDI is also accepting consulting assignments from other organizations in a selective manner.

Health, Safety and Environment Management

BHEL's commitment towards environment is reflected in all its activities, products and services, providing safe and healthy working environment to all stakeholders. In conformity with its concern for environment, the company has taken up a number of Environment Improvement Projects(EIPs), which include projects like plantation of 31 lakh trees, 47 Lakh Sq. M of green coverage, and 110 rainwater harvesting plants and energy and resource conservation projects in and around manufacturing units. These projects are aimed at enriching the environment, conservation of precious resources like water, energy, fuel, oil etc.

BHEL has been actively developing and acquiring clean technologies for power generation enabling its customers to minimize the impact of power generation on the environment. Reinforcing its commitment to optimum utilization of natural resources as well as its concern for the environment, BHEL has developed dynamic classifier system to improve combustion efficiency of boiler and reduction of NOx emission. The company has taken up Clean Development Mechanism (CDM) projects to reduce greenhouse gas emissions in a more focused and vigorous way. A broad reference list of CDM activity projects both of in-house implementation and joint claim projects with customers has been generated. CDM is a planned activity for each Unit and carbon credit forms part of budgeted activity.

BHEL has supplied 210 Sq.Mtr. space grade solar panels and 28 space quality batteries to ISRO for their space program. In the context of Jawaharlal Nehru National Solar Mission, BHEL shall be executing the orders for Renovation and Operation & Maintenance of SPV plants (aggregate 2.15MWp) at various Islands of Lakshadweep. In conformity with Green energy initiative, an energy efficient largest single cylinder non-reheat steam turbine for 100-140MW application has

already been developed to harness waste heat.

The company won the prestigious Golden Peacock Award for Occupational Health & Safety 2010 from the Institute of Directors for significant achievements in the field of Occupational Health & Safety.

Corporate Social Responsibility

BHEL has developed a CSR scheme and its Mission Statement on CSR is- "Be a Committed Corporate Citizen, alive towards its Corporate Social Responsibility".

Fostering the tradition of repaying the society at large by actively participating in the welfare of local communities through numerous Corporate Social Responsibility initiatives, BHEL undertakes socio-economic and community development programmes to promote education, improvement of living conditions and hygiene in villages and communities located in the vicinity of its manufacturing plants and project sites spread across the country. Thrust is being given in eight areas- Self-employment generation, Environment protection, Community development, Education, Health management & medical aid, Orphanages & Old-age Homes, Infrastructural development and Disaster/ Calamity Management. In addition, BHEL provides financial assistance to various NGOs/Trusts/ Social Welfare Societies that are engaged in social activities throughout the country.

In conformity with CSR Guidelines issued by Department of Public Enterprises BHEL has adopted its CSR Policy from 2010-11. Its constant endeavors were appreciated and recognized at the "CSR Thought Leadership conclave" organized by Wockhardt Foundation and BHEL was awarded the "India Shining Star CSR Award" for outstanding work in CSR sphere in the Capital Goods sector. CMD, BHEL was awarded the Distinguished Fellow Award 2010 from the Institute of Directors for outstanding contribution in the field of Corporate Governance and Corporate Social Responsibility.

Participation in the UN's Global Compact Programme

As the world's largest global corporate citizenship initiative, the Global Compact Program is the first and the foremost concern which is exhibiting and building the social legitimacy of business and markets. BHEL has continued to play a prominent part in the United Nation's Global Compact Programme on CSR by promoting the core values on human rights, labor standards, environment and anti-corruption and intends to advance these principles forming part of its strategy & culture within its sphere of influence. BHEL demonstrated its commitment through regular pooling of communication of progress (COP) on the UNGC website. BHEL per iodically submits annual Communication of Progress on the relevant principle of global compact in respect of Environment issues.

Company publicly advocates with its employees and other stakeholders and regularly incorporates its commitments towards Global compact programme through its Annual report, press conferences and other public documents.

Fig. (x) Bus Donated to Arivalayam- School for Special Children run by BHEL, Tiruchirapalli

Fig. (xi) Tree Plantation Drive at BHEL, Bhopal- a steps towards a cleaner environment

CHAPTER 1. INTRODUCTION

1.1: **HISTORY:** The commercial birth of the alternator can be dated back to august 24th1891 at Germany, so the natural choice for the field system was to achieve high availability of synchronous generators for electric energy production, attention has to be paid to the increase of availability of all generator subsystems and among them of the synchronous generator excitation system during a very long-term service. Requirements on availability of excitation system, beside its technical functions, have been always highland improvements are still being implemented a dc exciter. A dc current, creating a magnetic field that must be rotated at synchronous speed, energizes the rotating field-winding. The rotating field winding can be energized through a set of slip rings and brushes (external excitation), or from a diode-bridge mounted on the rotor (self-excited). The rectifier-bridge is fed from a shaft-mounted alternator, which is itself excited by the pilot exciter. In externally fed fields, the source can be a shaft-driven dc generator, a separately excited dc generator, or a solid-state rectifier. Several variations to these arrangements exist. In an alternator, when the rotor rotates the stator conductors (being stationary) are cut by the magnetic flux, hence they have induced e.m.f produced in them. To produce magnetic flux the rotor of synchronous machine needs a dc field current. This field current is supplied and controlled by excitation system. he 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.

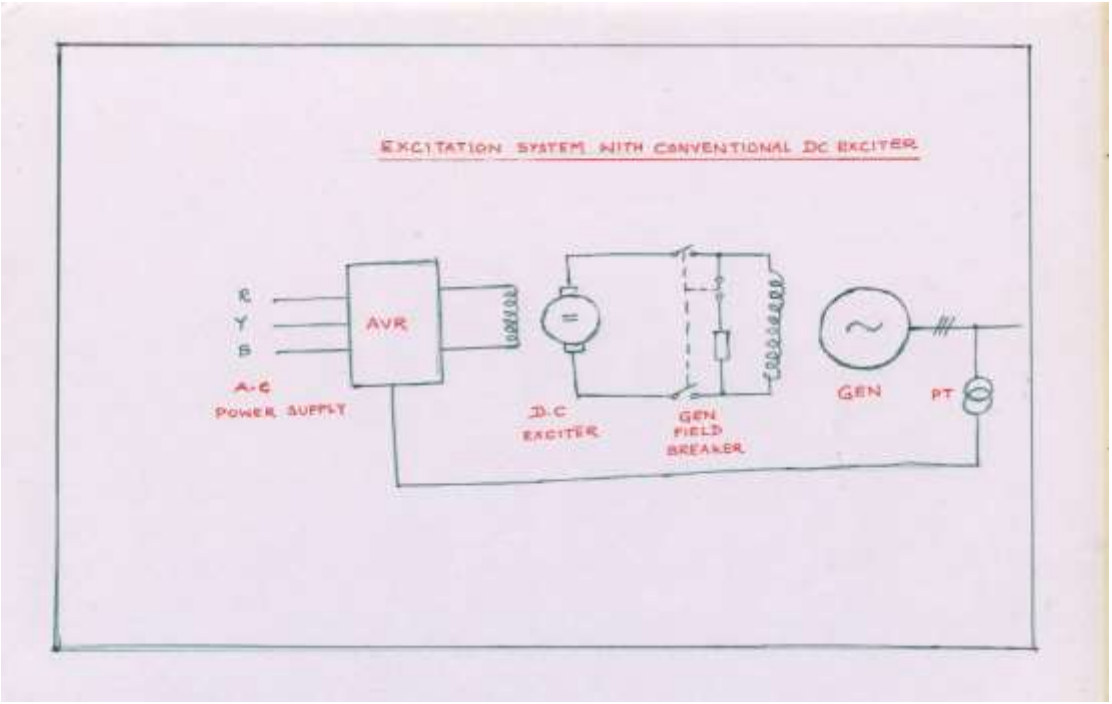

Figure 1. Block Diagram of Conventional Excitation system.

1.2: BASIC KINDS OF EXCITERS

1.2.1. Static exciters (shunt and series)

In static excitation system, the excitation power is derived from the generator output through an excitation transformer. In 210 MW set, the primary voltage of excitation transformer is 15—75 KV. lt steps down to 575V (SCR) bridge or thyristor bridge.

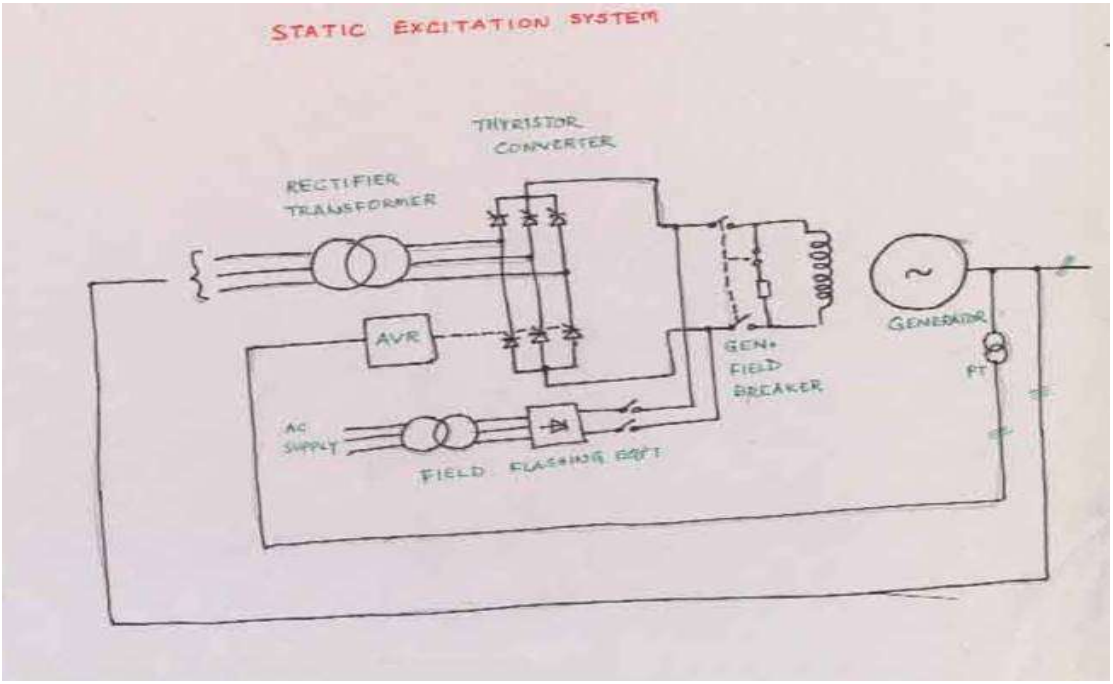

Figure 2. Block Diagram of Static Excitation system.

1.2.2. Rotating Exciters (Brush and brushless)

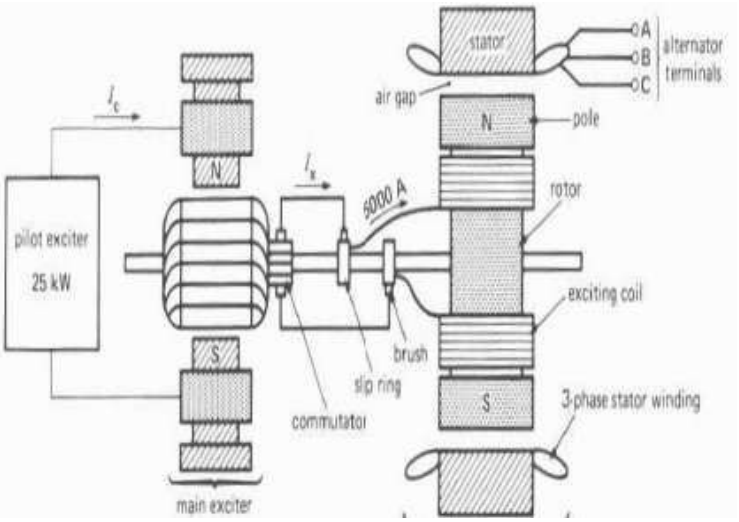

Figure 3.Brush exciter with slip ring

In the system DC power source is of rotating type, which in normally coupled to the main generator rotor.

1.2.2.1. Rotating With Brush:

i) For a Small Machine

The function of the brush is to collect current from commutator. It is usually made of carbon or graphite and are in the shape of rectangular block. It requires collector ring, brushes or commutators. DC supplied to the rotor field by a dc generator called exciter. This exciter may be supplied current by smaller dc generator called pilot exciter. DC o/p of main exciter is given to the field winding of synchronous machines through brushes and slip rings. But this arrangement is not very sensitive or quick acting when change of field current is required by synchronous machines.

ii) For Medium Size Motor

AC exciter is used in place of DC exciter. AC exciter is 3 phase ac generator. O/P is rectified and supplied through brushes and slip rings to the rotor wdg. Of main sync. m/c.

1.2.2.2. Brushless Rotating: The excitation requires very large problem of conveying such amount of power through high speed sliding contacts becomes formidable and at present large sync. Generator and motor are using brushless excitation system. Brushless exciter is small direct coupled ac generator with its field circuit on stator and from circuit on motor the 3 phase o/p of ac exciter generator is rectified by solid state rectifier. The rectified o/p is directly connected to the field winding, thus eliminating the use of brushes and slip ring. The DC exciter suffered commutation and brush gear problem but also offered certain advantages. Increased demand for higher excitation currents parallel by advances in semiconductor technology brought about the introduction of the rectified ac exciter. These where either static semiconductor diode rectifiers supplying the generator field winding via slip ring, or brushless system which carry the diode rectifier on shaft . To maximize the plant availability under black start condition, reliance on external electrical supplies is kept minimum by using direct driven permanent magnet pilot exciters. The development of solid state silicon diode with its inherent robustness and reliability, made possible the design of compact rectifier system that can be rotated at rated generator speed.

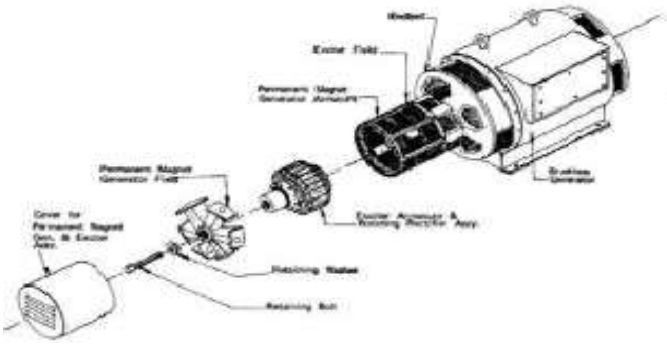

Figure 4.Brushless Exciter with Permanent Magnet Generator (Pilot Exciter)

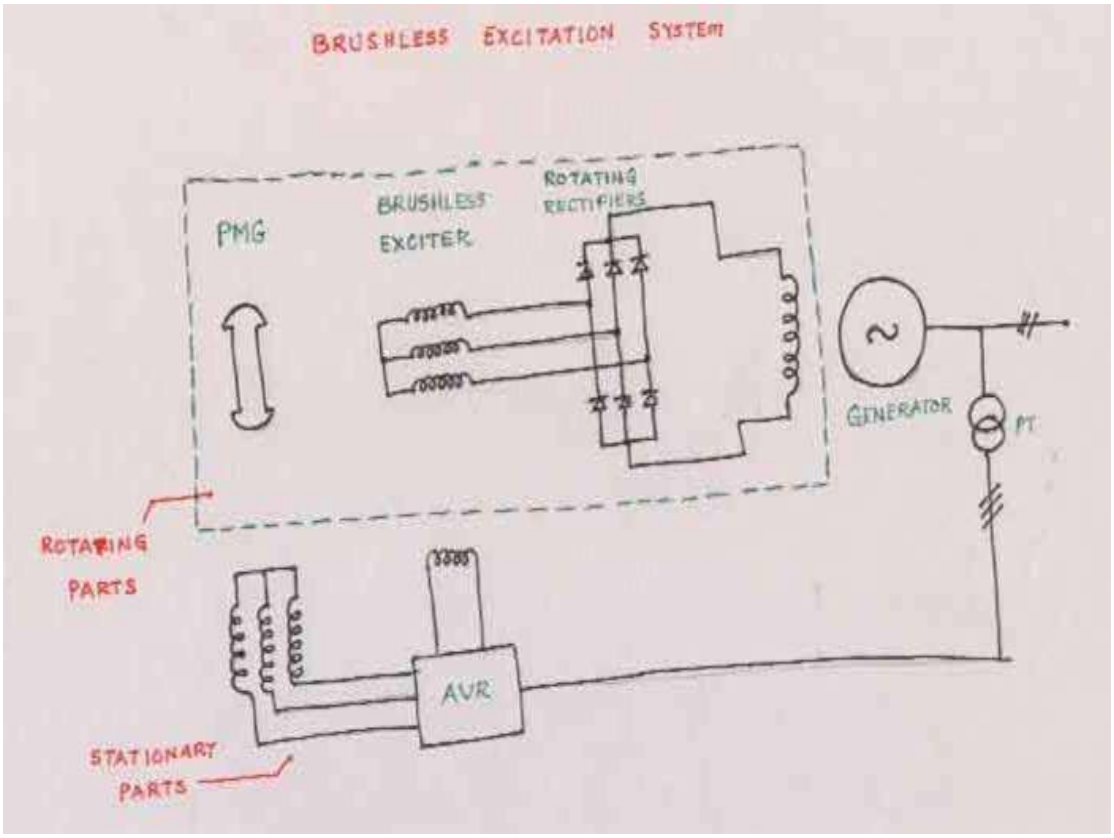

Figure 5.Block Diagram of Brushless Excitation System

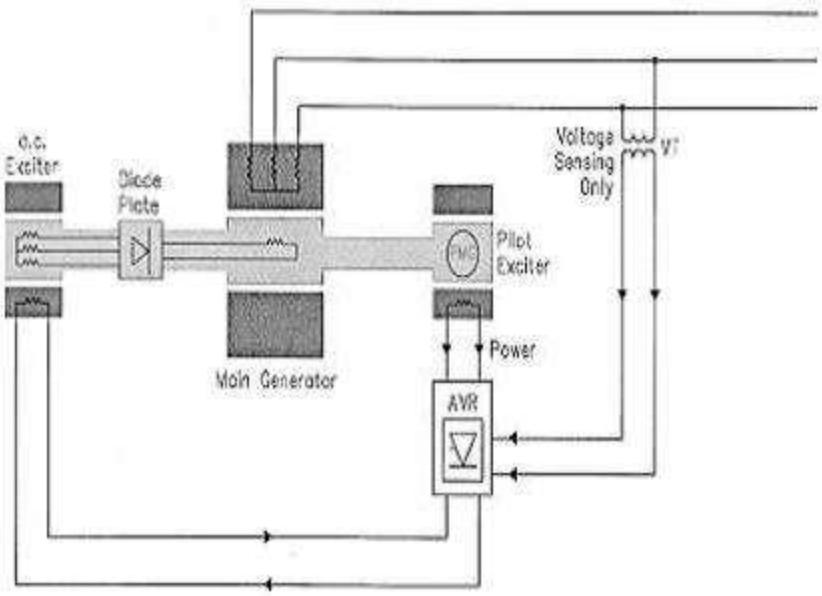

Figure 6. Block Diagram of Brushless Excitation System

CHAPTER 2. CONSTRUCTIONAL FEATURES OF A BRUSHLESS EXCITATION SYSTEM

2.1: Basic Arrangement of a Brushless Excitation system: The three phase pilot exciter has a revolving field with permanent magnet poles. The three phase ac generated by the permanent magnet pilot exciters is rectified and control by the TVR to provide the variable dc current for exciting the main exciters. The three phase ac induced in the rotor of the main exciters is rectified by the rotating rectifier bridge and fed to field winding of the generator rotor through the dc leads in the rotor shaft.

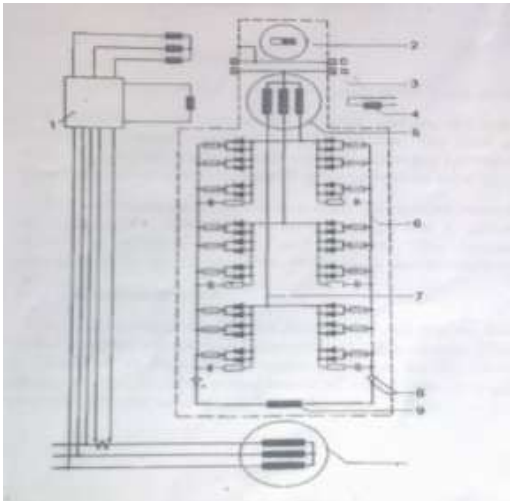

Figure 7. Basic Arrangement of Brushless Excitation System.

Key: 1.Automatic voltage regulator 2.Permanent magnet pilot exciter 3.Slip ring for field ground fault detection 4.Qudrature axis measuring coil 5.3-Φ main exciter 6.Diode rectifier set 7.Three phase lead 8.Multi-contact connector 9.Rotor winding of turbo generator 10.Stator winding of turbo generator.

2.2: Main parts of Brushless Excitation system:

2.2.1: 3-Φ Main Exciter: The three phase main exciter is a six pole revolving armature unit. Arranged in the stator frame are the poles with the field and damper winding. The field winding is arranged on the laminated magnetic poles. At the poles shoe bars are provided, their ends being connected so as form a damper winding. Between two poles a Quadrature axis coil is fitted for inductive measurement of the exciter current. The rotor consists of slack laminations, which are compressed by through bolts over compression rings. The three phase winding is inserted in the slots of the laminated rotor. The winding conductors are transposed within the core length, and the end turns of the rotor winding are secured with steel bands. The connections are made on the side facing the rectifier wheels. Winding ends are run to a bus ring system to which the three phase leads to the rectifier wheels are also connected. After full impregnation with synthetic resin and curing, the complete rotor is shrunk on to the shaft. A journal bearing is arranged between main exciter and pilot exciter and has forced oil lubrication from the turbine oil supply.

Figure 8. DC Exciter Armature

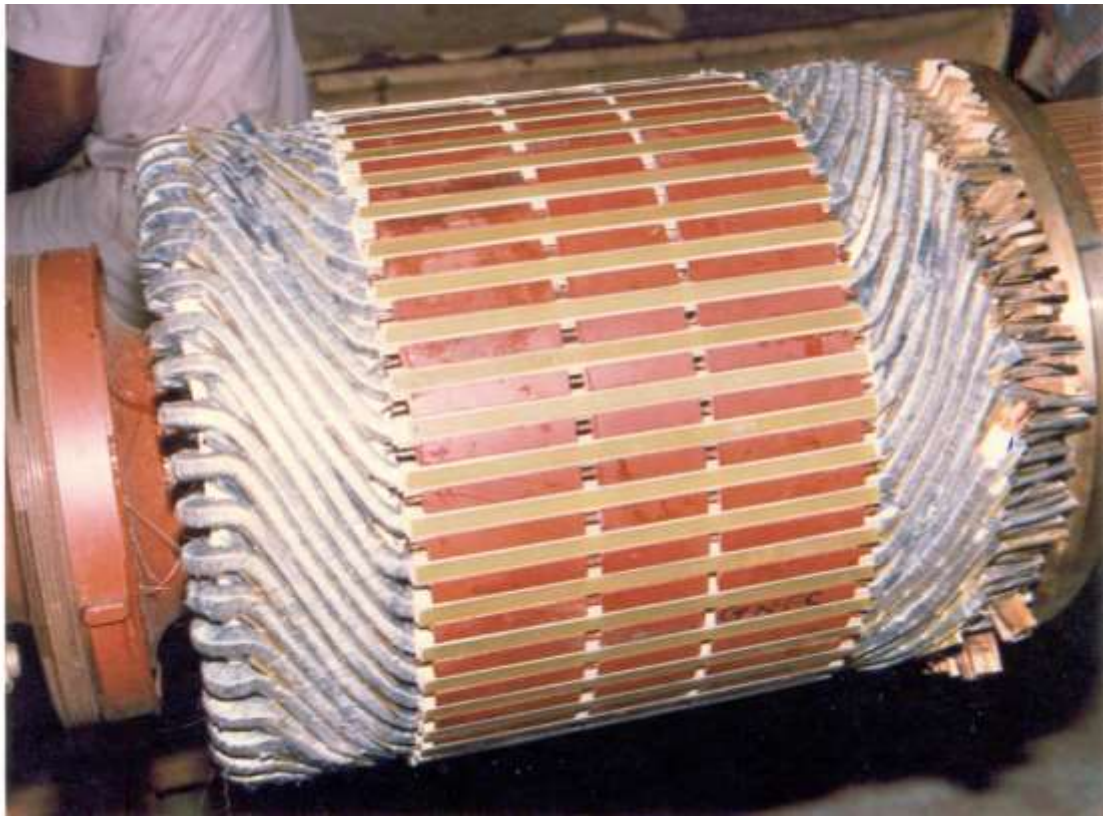

Figure 9. DC Exciter Armature Winding

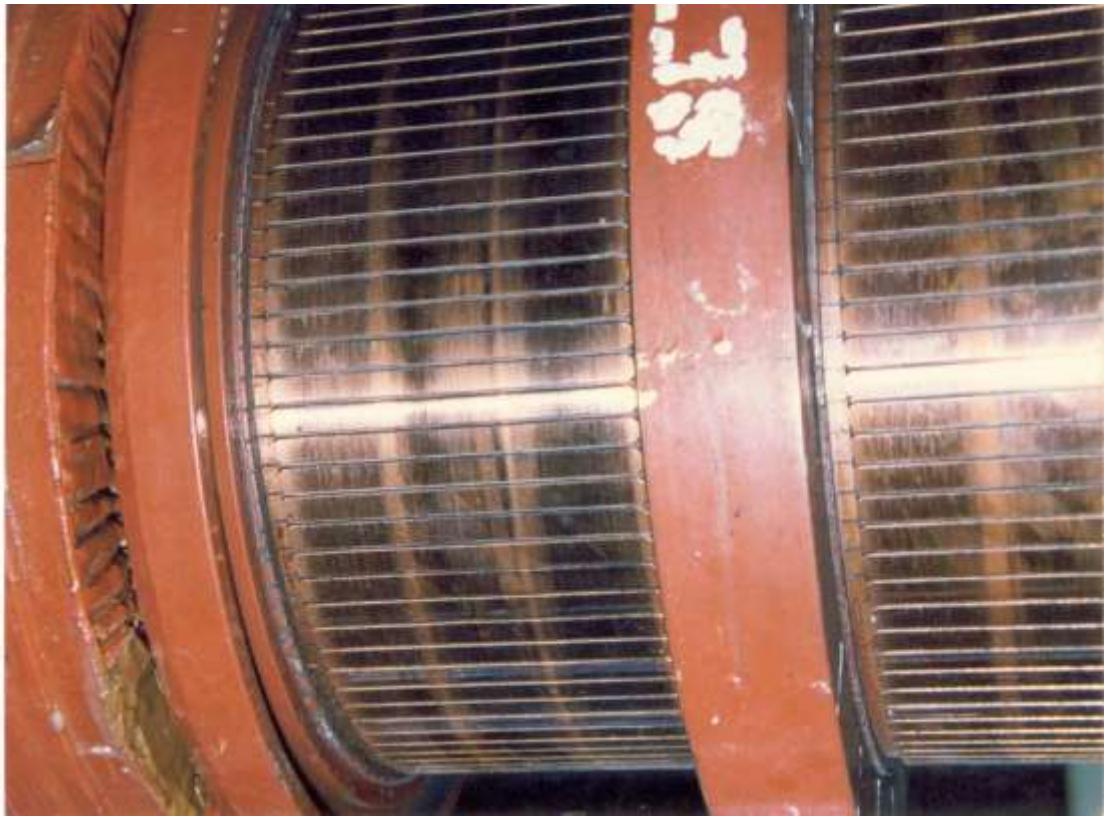

Figure 10. DC Exciter Commutator

2.2.2: Diode Wheels: The main components of the rectifier wheels are the silicon diodes which are arranged in the rectifier wheels in a three phase bride circuit. The internal arrangement of the diodes is illustrate in the fig. the contact pressure for the silicon wafer is produced by the plate spring assembly. The arrangement of the diodes is such that this contact pressure is increased by the centrifugal force during rotation. Figure shows the additional components contains in the rectifier wheels. Two diodes each are mounted in each aluminum alloy heat sink and thus connected in parallel. Associated in heat sink is a fuse, which serves to switch off the two diodes if one diodes fails (loss of reverse blocking capacity). For suppression of momentary voltage peak arising from commutation, each wheel is provided with six RC networks consisting of one capacitor and the one damping resistor each, which are combining in a single resin-encapsulated unit. The insulated and shrunken rectifier wheels serves as a dc buses for negative and positive sides of the rectifier bridge.

The two wheels are identical in their mechanical design and differ only in forward directions of the diodes. The direct current from the rectifier wheels is fed to the DC leads arranged in the center bore of the shaft via radial bolts. The three phase alternating current is obtained via copper conductor arranged on the shaft circumference between the rectifier wheels sand the three phase main exciter. The conductor are attached by means of banding clips and equipped with screw on lugs for the internal diodes connections. One three phase conductor each is provided for the four diodes of the heat sink set.

Figure 11. Diode Wheel and Fuses mounted on wheel.

Figure 12. Complete finished Rotor

2.2.3: Automatic Votage Regulators: Voltage transformers provide signals proportional to line voltage to the AVR where it is compared to a stable reference voltage. The difference (error) signal is used to control the output of the exciter field. For example, if load on the generator increases, the reduction in output voltage produces an error signal which increases the exciter field current resulting in a corresponding increase in rotor current and thus generator output voltage. Due to the high inductance of the generator field windings, it is difficult to make rapid changes in field current. This introduces a considerable "lag" in the control system which makes it necessary to include a stabilizing control to prevent instability and optimize the generator voltage response to load changes. Without stabilizing control, the regulator would keep increasing and reducing excitation and the line voltage would continually fluctuate above and below the required value. Modern voltage regulators are designed to maintain the generator line voltage within better than +/- 1% of nominal for wide variations of machine load.

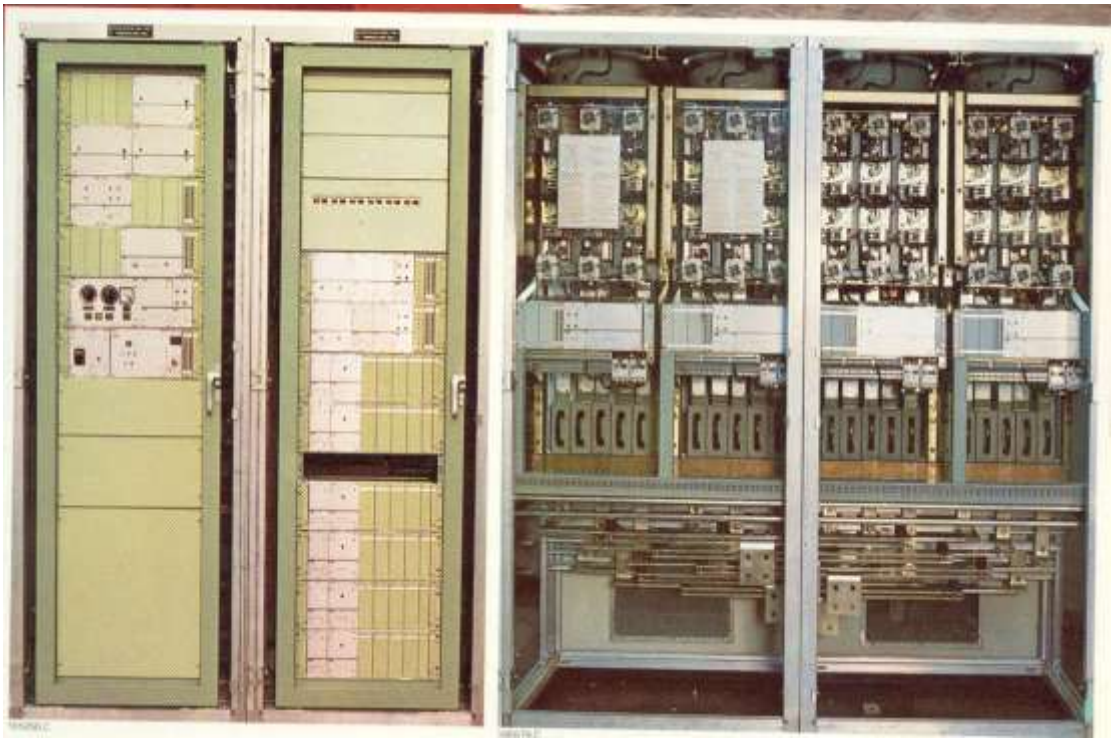

Figure 13. Static Excitation Equipment

2.2.4: 3-Φ Pilot Exciter: The three Phase pilot exciter is a 16 pole revolvingfield unit. The frame accommodates the laminated core with the three phase winding. The rotor consists of a hub and the external poles shoe with bolts. The rotor hub is shrunk on to the free shaft end.

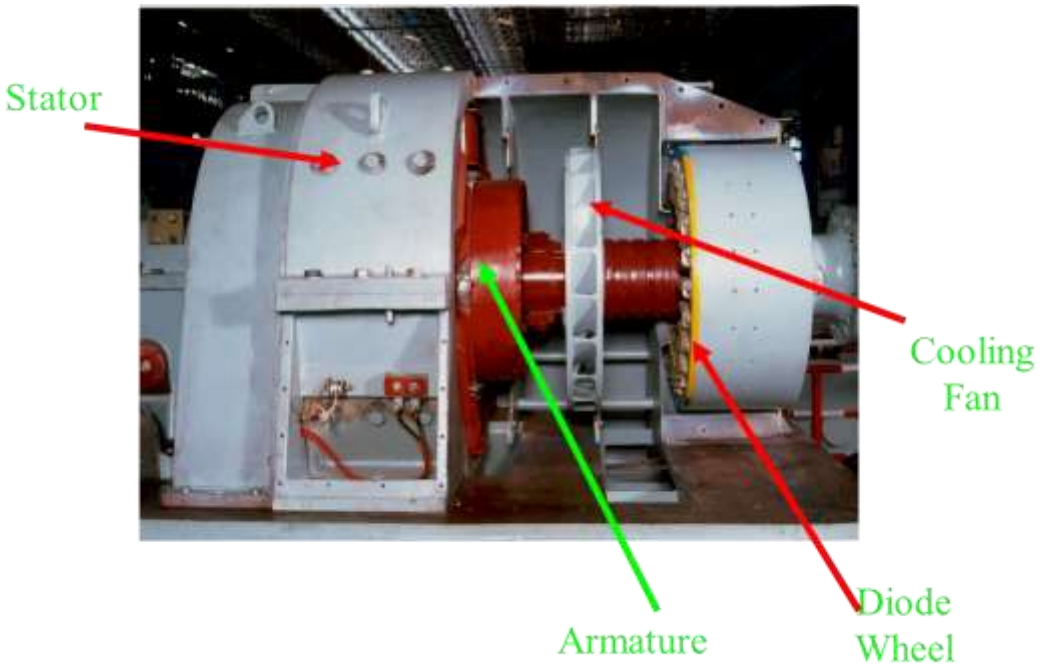

Figure 14. Brushless Excitation system Complete Assembly

CHAPTER 3. COOLING SYSTEMS OF EXCITERS

3.1: COOLING OF EXCITER:

The exciter is air cooled. The cooling air is circulated in a close circuit and re-cooled in two cooler sections arranged alongside the exciter. The complete exciter is house in an enclosure through which the cooling air circulates. The rectifier wheels, house in their own enclosure, draw the cool air in at both ends and expel the warmed air to the compartment beneath the base plate. The main exciter enclosure receives cool air from the fan after it passes over the pilot exciter. The air enters the main exciter from both ends and is passed into ducts below the rotor body and discharged through radial slots in the rotor core to the lower compartment. The warm air is then returned to the main enclosure via the cooler sections.

3.1.1:Hydrogen cooling: Hydrogen cooled synchronous condensers operating at speed up to 900 r.p.m. have been furnished with direct connected main exciter located in hydrogen filled compartment which can be isolated from the main condenser compartment when maintenance is to be done on the exciter. It has been found that hydrogen cooling of exciter not only reduces the temperature rise of exciter but also decreases the wear of the commutator and brushes. Hydrogen cooling has been proposed for the exciters of turbo generator.

3.1.2: Emergency Cooling of Exciter: Emergency cooling is provided to permit continued operation in the event of cooler failure. In such an emergency, flaps in the hot and cold air compartments are automatically operated by actuators admitting cold air from outside the exciter enclosure and discharging the hot air through openings in base frame.

3.2: EXCITER DRYING:

A dryer (dehumidifier) and an anti-condensation heating system are provided to avoid the formation of moisture condensate inside the exciter with the turbine-generator at rest or on turning gear.

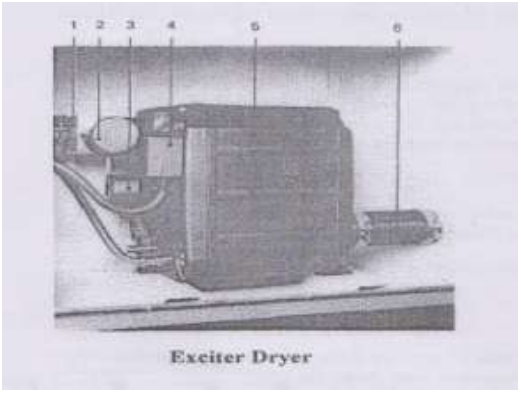

Figure 15.Exciter dryer

3.2.1: MODE OF OPERATION: The dryer dehumidifies the air within the exciter enclosure. The dryer wheel is made of a non-flammable material. On its inlet side, the wheel is provided with a system of tubular ducts, the surfaces of which are impregnated with a highly a highly hygroscopic material. The tubular ducts are dimensioned so that a laminar flow with low pressure loss is obtained even at high air velocity. The moisture absorbed by the dryer wheel is removed in a regeneration section by a stream of hot air directed through the wheel in the opposite direction of the inlet air and then discharged to the atmosphere. A shutoff valve in the dry air outlet line prevents that contaminated air from the powerhouse will be drawn during load operation of the exciter.

3.2.1.1: Adsorption Section: The air to be dehumidified passes through the adsorption section of the dryer wheel, with part of the moisture contained in the air being removed by the adsorbent material, is that lithium chloride. The moisture is removed as a result of the partial pressure drop existing between the air and the adsorbent material.

3.2.1.2: Regeneration Section: In the regeneration section of the dryer wheel, the accumulated moisture is removed from the dryer wheel by the heated regeneration air. Continuous rotation of the dryer wheel ensures continuous dehumidification of the air within the exciter.

3.3: STROBOSCOPE FOR FUSE MONITORING:

The fuses on the rectifier wheels may be checked during operation with the stroboscope. The stroboscope is located adjustment to the rectifier wheel in the exciter enclosure so that the fuses may be observed from outside the exciter enclosure while controlling the stroboscope. The observation period for one full revolution of the rectifier wheel (360˚) is approximately 25 sec. at approximately 450˚, the stroboscope resets to the initial position of the wheel and repeats the scan. The continuous can be interrupted at any time to hold a stationary image.

CHAPTER 4. METERING AND SUPERVISORY EQUIPMENT FOR EXCITERS

4.1: SUPERVISION OF EXCITER:

The most essential measuring and supervisory devices at the exciter are:

- Temperature monitoring system
- Fuse monitoring system
- Ground fault detection system
- Excitation current measuring device

4.1.1: Temperature monitoring system: The exciter is provided with devices for monitoring the temperature of the cold air after the exciter cooler and the hot air leaving the rectifier wheels and main exciter.

4.1.2: Fuse monitoring system: The indicator flags of the fuses on the rectifier wheels may be checked during operation with the built in stroboscope.

4.1.3: Ground fault detection system: Two slip rings are installed on the shaft between the main exciter and the bearing. One is connected to the star point of the three phases winding of the main exciter and the other to the Frame. These slip rings permit ground fault detection. The field ground fault detection system detects high resistance and low resistance ground faults in the exciter field circuit. It is very important for safe operation of a generator, because a double fault causes magnetic unbalance with very high currents flowing through the faulted part, resulting in its destruction within a very short time. If the field ground fault detection system detects a ground faults, an alarm is activated at Re < 80kΩ (1^{st} stage).if the insulation resistance between the exciter field circuit and ground either suddenly or slowly drops to Re < 5kΩ the generator electrical protection is tripped (2nd stage).The generator is thus automatically disconnected from the system and de excited.

4.1.4: Excitation current measuring device: The excitation current is measured indirectly through a coil arranged between two poles of the main exciter. The voltage induced in this coil is proportional to the main excitation current thus enabling a determination of the excitation current.

CHAPTER 5. CONCLUSION

PERFORMANCE COMPARISION OF EXCITATION SYSTEMS

S. NO.	PARAMETER	CONVENTIONAL	BRUSHLESS	STATIC
01	RELIABILITY	GOOD	EXCELLENT	VERY GOOD
02	FLEXIBILITY OF OPERATION	GOOD	GOOD	VERY GOOD
03	POWER CABLING	HIGH	NIL	HIGH
04	EXC. RESPONSE	1.5 TO 2	1.5 TO 2	1.5 TO 3
05	MEASUREMENT OF Vf,If, & Tf	POSSIBLE	INDIRECT MEASUREMENT OF If,& Tf	POSSIBLE
06	SYSTEM RESPONSE	GOOD	GOOD	EXCELLENT
07	LAYOUT OF CUBICLE	COMPACT	COMPACT	REQUIRE MORE SPACE

Choice of excitation system depends on choosing between static and brushless. DC exciters are now obsolete. Static is preferred when direct on line starting of larger motors is envisaged wherein high cyclic loads are present and very high response is required.

Brushless is preferred when highest reliability and minimum maintenance are the main criteria.

Advantages of Brushless Excitation systems are:

- No brushes.
- Minimum maintenance.
- No power cabling.
- Minimum control room space.
- Highest reliability.

Disadvantages of Brushless Excitation System are:

- Limited flexibility of operation
- Costly
- Moderate nominal exciter response
- Maintenance of rotating machines

Salient features of Brushless Excitation system are:

- Redundancy in diodes.
- Fuses for diode protection
- Fuse failure detected by stroboscope
- Reverse in diode current capacity will reduce probability of failure.

Brushless excitation system is preferred with slip ring excitation system because the losses are minimized in large extent. So the efficiency also increases by use of brushless excitation system. This alternative eliminates the need for brush gear maintenance and reduces the overall unit size.

CHAPTER 6. REFERENCES

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