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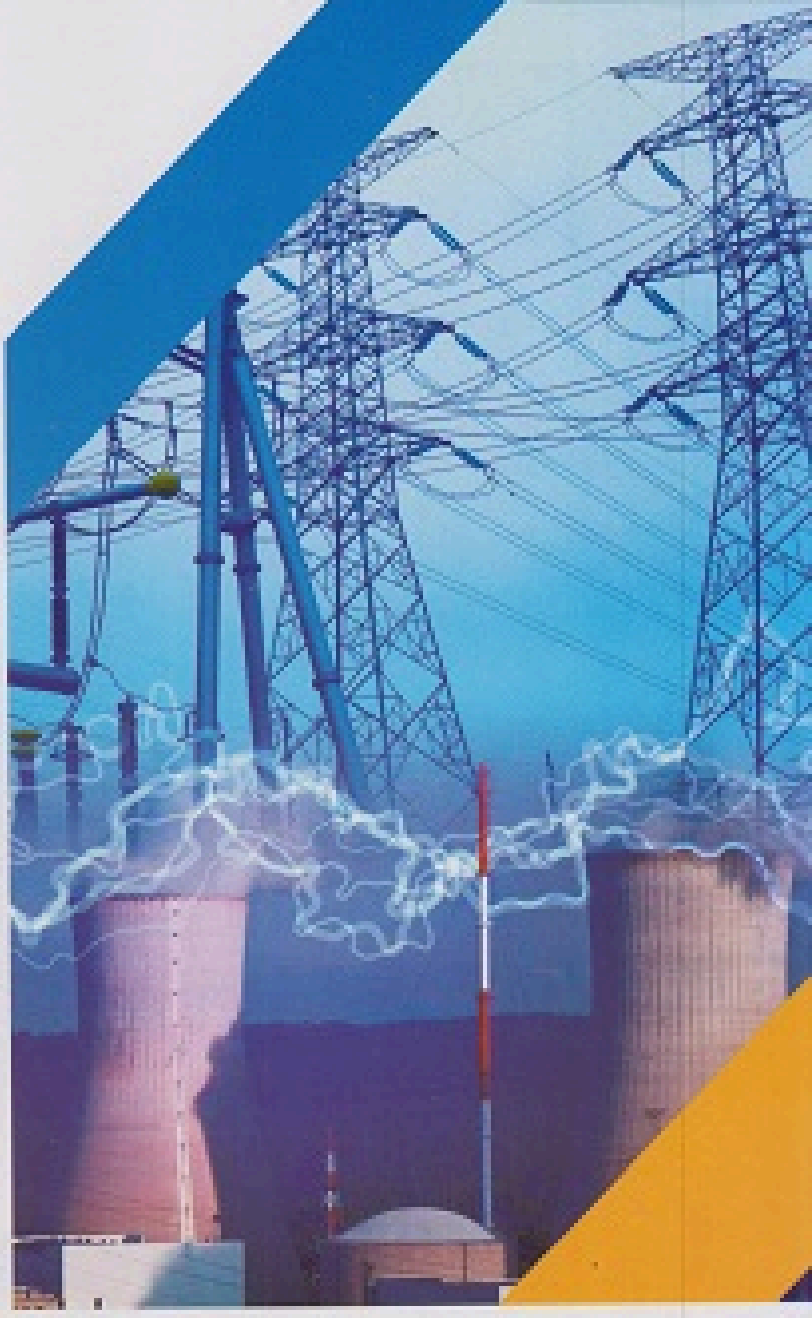
DBATU

Second Year (S.Y.) B. TECH Semester - IV Course in
ELECTRICAL ENGINEERING / ELECTRICAL & ELECTRONICS ENGINEERING / ELECTRICAL & POWER ENGINEERING

POWER SYSTEM

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NIRALI PRAKASHAN
ADVANCEMENT OF KNOWLEDGE

A TEXT BOOK OF

POWER SYSTEM

FOR

Semester – IV

SECOND YEAR (S.Y.) B. TECH COURSE IN
ELECTRICAL ENGINEERING / ELECTRICAL & ELECTRONICS ENGINEERING / ELECTRICAL & POWER ENGINEERING

Strictly According to New Revised Credit System Syllabus of
Dr. Babasaheb Ambedkar Technological University (DBATU),
Lonere, Dist. Raigad, Maharashtra.
(w.e.f 2021 - 2022)

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ADVANCEMENT OF KNOWLEDGE

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PREFACE

It gives us great pleasure to present the book **'Power System'** for the students of **Semester IV Second Year (S.Y.) B.Tech. Course in Electrical Engineering / Electrical & Electronics Engineering / Electrical & Power Engineering of Dr. Babasaheb Ambedkar Technological University (DBATU), Lonere, Dist. Raigad (Maharashtra).** This book is strictly as per the new revised syllabus, 2020 Pattern, effective from the Academic Year 2021 - 2022.

The Theory Course will have 4 Credits.

In New Revised Syllabus, there will be Internal Assessment (20 Marks), Mid Sem. Exam. (20 Marks) and End Sem. Exam. (60 Marks). End Sem. Exam. will be based on all Five Units.

The basic objective of this book is to bridge the gap between the vast contents of the reference books, written by the renowned International Authors and the concise requirements of Undergraduate Students. This book has been written in a comprehensive manner using Simple and Lucid language, keeping in mind student's requirements. The main emphasis has been given on exploring the basic concepts rather than merely the Information. Solved Examples and Exercises have been provided throughout the book at the end of the Unit. Also we have given **Model Question Papers** for practice at the end of the book.

Our special thanks to our family members, students and all those who directly or indirectly supported us in this project.

We also take this opportunity to express our sincere thanks to Shri. Dineshbhai Furia, Shri. Jignesh Furia, Mrs. Nirali Verma and entire team of Nirali Prakashan, namely Mrs. Deepali Lachake (Co-ordinator), who really have taken keen interest and untiring efforts in publishing this text.

We wish to make a special mention of the valuable contribution made by Late Shri M.P. Munde during the last two decades in reaching out to students, parents and teachers which eventually made **Nirali Prakashan, a brand of trust and quality in technical books**. Without his perseverance and zeal, successive editions would not have been possible.

The advice and suggestions of our esteemed readers to improve the text are most welcome and will be highly appreciated.

Pune **Authors**

SYLLABUS

Unit I: Electrical Power Generation **9 Hours**

Evolution of Power Systems, Typical Layout of an Electrical Power System—Introduction to different sources of energy. Construction and working of thermal power plants, Hydro power station, Nuclear Power Plant with neat block diagram of main parts. Descriptive treatment of alternator exciter & excitation systems, major electrical equipments in generating stations.

Unit II: Electrical Design of Overhead Transmission Lines **9 Hours**

Line conductors, inductance and capacitance of single phase and three phase lines with symmetrical and unsymmetrical spacing, concept of GMD and GMR, Composite conductors transposition, bundled conductors, and effect of earth on capacitance skin effect, proximity effect, Ferranti Effect.

Corona: Introduction, Factors affecting corona loss arid methods of reducing corona loss, Disadvantages of corona.

Unit III: Mechanical Design of Transmission Lines **8 Hours**

Types of conductors, Choice of conductor materials, Stranded copper & ACSR conductor, Insulation consideration, Different types of insulator, supports, distribution of voltage across the insulator string, String efficiency. Effect of wind & ice coating on transmission line, sag due to equal & unequal supports, with their derivation, Numericals.

Unit IV: Performance of Transmission Lines **8 Hours**

Classification of overhead transmission lines, important terms, performance of single phase short transmission lines, three phase short transmission fines, effect of load power factor on regulation and efficiency, different types of medium transmission line, Analysis of long transmission lines, generalized constant of transmission line, determination of generalized constant of transmission lines, percentage regulation, Transmission efficiency, numerical based on above.

Unit V: AC & DC Distribution **8 Hours**

Classification of Distribution system, Requirement of distribution system, design consideration in distribution system. AC Distribution. Calculations, method of Solving AC Distribution problem, three phase unbalanced load, four wire unbalanced star connected load, ground detector. DC Distribution: types, DC distribution calculation, three wire DC system.

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UNIT I

ELECTRICAL POWER GENERATION

1.1 EVOLUTION OF POWER SYSTEM

- Evolution to the present state of the power systems owes its start to the Edison, in September 1882, Pearl Street Generating Station in lower Manhattan, New York, USA, the first power station in the world.
- Since then power systems have developed into large central generating stations supplying electricity, through high voltage networks, to local distribution systems, industry Commercial and residential.
- This was a dc system comprised of a steam-engine driven dc generator. It was supplied at 110 V through an underground cable system. It supplied power to 59 customers within an area roughly 1.5 km in radius. The load consisted of incandescent lamps. In 1884, with the development of motors by Frank Sprague, motor loads were added to such systems.
- The commercial use of electricity began in the late 1870s when arc lamps were used for lighthouse illumination and street lighting.
- The transformer was designed by Lucien Gaulard and John Dixon Gibbs created the real beginning to the electrical power systems we are familiar with today. The transformer was used to light up the lamps for a distance of twenty five miles but the more distance that the lamp was from the generator source, the dimmer the light it emitted was.
- This is because Gaulard and Gibbs did not connect the primaries of the different transformers in a series that would allow the lamps on the end to receive the same amount of power as the lamps on the beginning phase. The development of the transformer and ac transmission by L. Gaulard and J.D. Gibbs of Paris, France, led to ac electric power systems.
- Till 1886, the company Westinghouse, had a proven system located in Great Barrington, Massachusetts. In 1886, William Stanley, an associate of Westinghouse, developed and tested a commercially practical transformer and ac distribution system for 150 lamps at Great Barrington, Massachusetts.
- The success of Westinghouse could largely be because they connected the transformers in a certain way such that the lamp on the end of the line could receive the same amount of voltage as the first one did. In 1890 these networks were recognized everywhere providing people with the ease of electric lighting.
- By 1888, Nikola Tesla held several patents on ac motors, generators, transformers and transmission systems. Westinghouse bought the patents to these early inventions and they formed the basis of the present-day ac systems.
- In the 1890s, there was considerable controversy over whether the electric utility industry should be standardized on dc or ac. There were arguments between Edison, who advocated dc and Westinghouse, who favoured ac.
- By the turn of the century, the ac system had gained weightage over the dc system for the following reasons:
  - ➢ AC generators are much simpler than dc generators.
  - ➢ Voltage levels can be easily transformed in ac systems, thus providing the flexibility for use of different voltages for generation, transmission and consumption.
  - ➢ AC motors are much simpler and cheaper than dc motors.
  - ➢ The ac versus dc controversy concluded with victory for the ac system.
- With the development of mercury arc valves in the early 1950s, High Voltage DC (HVDC) transmission systems became economical in special situations. The first modern commercial application of HVDC transmission occurred in 1954 when the Swedish mainland and the island of Gotland were interconnected by a 96 km submarine cable. With the introduction of thyristor valve converters, HVDC transmission turn out to be even more attractive. The first application of an HVDC system using thyristor valves was at Eel River in 1972 – a back-to-back

scheme providing an asynchronous tie between the power systems of Quebec and New Brunswick.

- Power systems engineers have always been on the forefront of exploring and utilizing any new enabling technology. They have worked hard to make operation of power systems smarter since 1882. Every feature of the electric power systems, i.e. may be Infrastructure, planning, operation, measurement and control, protection has made tremendous advances over the past hundred years.

1.2 TYPICAL LAYOUT OF AN ELECTRIC POWER SYSTEM

- A power system is an interconnected network with components converting non electrical energy continuously into the electrical form and transporting the electrical energy from generating sources to the loads/users. The flow of electrical power from the generating station to the consumer is called an electrical power system or electrical supply system.
- Power generated is transmitted over large distances to load centers with the help of transmission lines. It is distributed to small as well as large consumers through distribution system. Fig. 1.1 shows the general arrangement of a.c. power system.

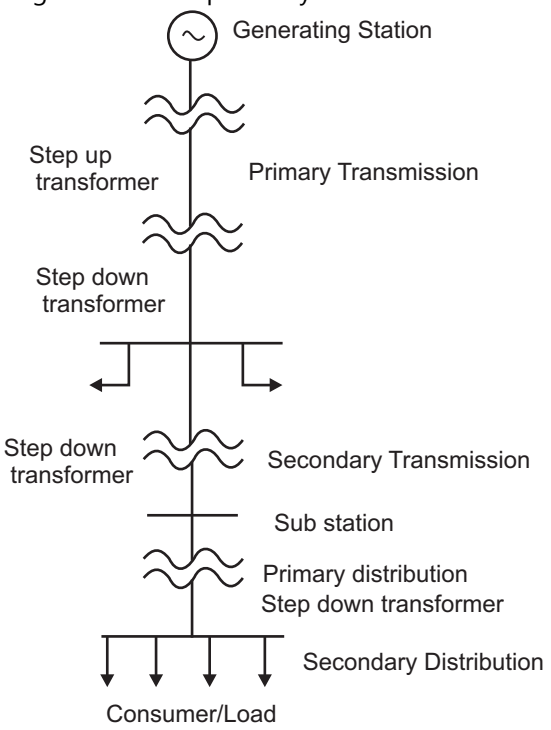


Fig. 1.1

Power System can be Divided into Three Sub-Systems:

1. **Generation:** Generating and / or sources of electrical energy.
2. **Transmission:** Transporting electrical energy from its sources to load centers with high voltages (115 kV and above) to reduce losses.
3. **Distribution:** Distributing electrical energy from sub-stations to end users / customers.

- The generator converts non electrical energy to electrical energy. Transformers connect generators to transmission system and from transmission system to distribution system with bus bars. Their main function of transformer is stepping up the lower generation voltage to the higher transmission voltage and stepping down the higher transmission voltage to the lower distribution voltage. High voltage in transmission system reduces the losses in the grid.

Fig. 1.2 shows the general structure of electric power generation, transmission and distribution system.

It has following main components :

(a) Generating Station :

- At the generating station, an electrical power is generated.
- Electric power is produced by generating units which convert primary energy into electric energy. Primary energy can be obtained from sources, such as fossil fuel and nuclear, hydro, wind and solar power. The process used to convert this energy into electric energy depends on the design of the generating unit. From the operational perspective of the electric power system, generating units are classified into three categories:
  - ➢ **Base-load:** Base load units are used to meet the constant, or base, power needs of the system. They run continuously throughout the year except when they have to be shut down for repair and maintenance. They must be reliable and economical to operate. Because of their low fuel costs, nuclear and coal plants are generally used as base load units, also are run-of-the-river hydroelectric plants.
  - ➢ **Intermediate:** Intermediate units are also called as cycling units. They operate for extended periods of time, unlike base load units, not at one power continuously. They have the ability to vary their output more quickly than base load units.
  - ➢ **Peak Units:** Peak units operate only when the system power demand is close to its peak. Gas turbine and hydroelectric plants with reservoirs are generally used as peak units.

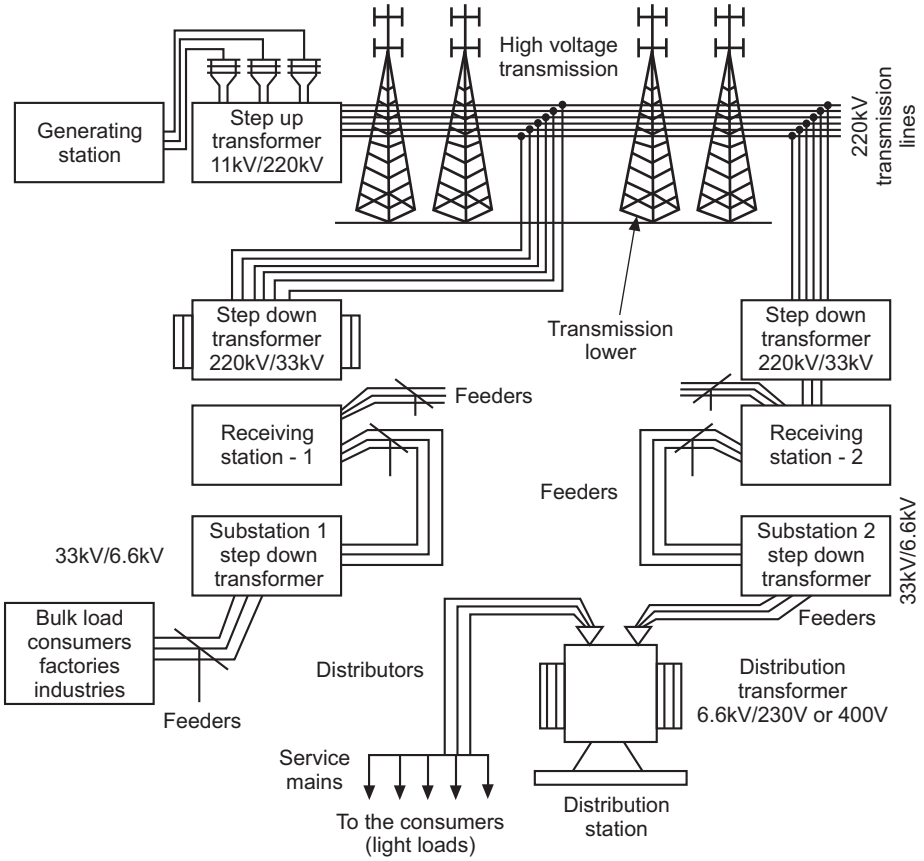


Fig. 1.2: Schematic Representation of a typical transmission distribution scheme

(b) Primary Transmission :

- The transmission system carries electric power over long distances from the generating units to the distribution system. The transmission network is composed of power lines and stations/sub-stations.
- The primary transmission uses 3 phase 3 wire system. For the economic aspects, the voltage level is increased to 132 kV, 220 kV or more, with the help of step up transformer. Hence this transmission is also called high voltage transmission.

(c) Secondary Transmission :

- The primary transmission line continues via transmission towers till the receiving stations. Using step down transformer, the voltage at the receiving station is reduced. Now electric power is transmitted to various sub-stations. Sub-transmission carries power over shorter distances and it is typically used to connect the transmission network to multiple nearby locations relatively small distribution networks. Transformers at transmission sub-stations convert transmission voltages down to lower levels to connect to the sub-transmission network or directly to the distribution network.
- At the receiving stations, the voltage level is reduced to 22 KV or 33 KV using the step down transformer. There can be more than one receiving stations. The power is then transmitted to various sub-stations at reduced voltage level of 22 KV or 33 KV, using overhead 3 phase 3 wire system. This is secondary transmission. The conductors used for the secondary transmission are called feeders.

(d) Primary Distribution :

- Energy from the sub-station is carried through feeders to the distribution transformers.
- At the sub-station the voltage level is reduced to 6.6 KV, 3.3 KV or 11 KV with the help of step down transformers. It uses three phase three wire underground system. The power is transmitted to the local distribution centers. Primary distribution also called as high voltage distribution.

(e) Secondary Distribution :

- Power from primary distribution system delivered to distribution sub station. Secondary distribution supplies power to the consumers. Sub stations are located near consumers where voltage is step down.
- At the local distribution centers, there are step down distribution transformers. The voltage level of 6.6 KV,

11 KV is further reduced to 400 V using distribution transformers. It may be reduced to 230 V. The power is transmitted through 3 phase 4 wire system. The voltage between any two lines is 400 V. while the voltage between any of the three lines and a neutral is 230 V.

- All these important networks are connected with the help of conductors and various step up and step down transformers..

1.3 INTRODUCTION TO DIFFERENT SOURCES OF ENERGY

(a) Renewable Energy Sources: They are called renewable energy sources because they are naturally replenished. Day after day, the sun shines, plants grow, wind blows and rivers flow. While renewable energy resources have the advantage of unlimited supply over the long haul, they are limited in their availability at any given moment.

The major types or sources of renewable energy are:

- ➢ Solar energy -from the sun
- ➢ Geothermal energy -from heat inside the earth
- ➢ Wind energy
- ➢ Biomass from plants
- ➢ Hydropower -from flowing water

(b) Non Renewable Energy Sources: These energy sources are called non renewable because their supplies are limited to the amounts that we can extract from the earth. Non-renewable energy resources are available in limited supplies, usually because they take a long time to replenish. The advantage of these non-renewable resources is that power plants that use them are able to produce more power on demand. The non-renewable energy resources are:

- ➢ Coal
- ➢ Nuclear
- ➢ Oil
- ➢ Natural gas

Table 1.1

Renewable Resources	Non-renewable Resources
Renewable resources cannot be exhausted over time	Non-renewable resources deplete over time
Renewable resources include sunlight, water, wind, biomass, geothermal sources such as hot springs and fumaroles	Non-renewable energy includes fossil fuels such as coal and petroleum.
Most renewable resources have low carbon footprint and low carbon emissions.	Non-renewable energy has a comparatively higher carbon footprint and carbon emissions.
Generating electricity using technologies running on renewable energy is costlier than generating it with fossil fuels. The upfront cost of renewable energy is high.	Non-renewable energy has a comparatively lower upfront cost.
Infrastructure for harvesting renewable energy is prohibitively expensive and not easily accessible in most countries.	Cost-effective and accessible infrastructure is available for non-renewable energy across most countries
Requires a large land or offshore area, especially for wind farms and solar farms	Lower area requirements

In this section we will be discussing about renewable energy sources in brief.

1.3.1 Solar Energy

- Solar energy is the most readily available source of energy. It is the non-conventional sources of energy and is non-polluting. India is one of the few countries with plenty of solar energy. India receives solar energy over 5000 trillion kWh/year, which is far more than the total energy consumption of the country.
- Solar thermal energy is being used in India for heating water for both industrial and domestic purposes. Solar energy can also be used generate electricity. Solar Photovoltaic (SPV) cells convert solar radiation into DC voltage which can either be used directly or can be stored in the battery. The stored electrical energy can be used during night.

Advantages of Solar Power

- Solar energy is a clean and renewable energy source.
- Solar energy can be used in remote areas where it is too expensive to extend the electricity power grid.
- Solar energy will last forever whereas it is estimated that the world's oil reserves will last for 30 to 40 years.
- Solar energy causes no pollution.
- There are no moving parts in a solar cell. Very little maintenance is needed to keep solar cells running.

Disadvantages of Solar Power

- Solar collectors, panels and cells are relatively expensive to manufacture although prices are falling rapidly.