Professional Engineering Exam

Electric Power Engineering

Study Guide

Education and Training Evaluation Commission (ETEC)
National Center for Assessment (NCA)

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1. Aim:

The objective of this Instruction Manual is to provide guidelines for the NCA proposed Professional Engineers Exam. These guidelines cover the eligibility conditions, the grading and passing conditions, the structure of the exam and the distribution of exam questions among various areas. In essence, this Instruction Manual represents a "bridge" between the developed exam standards and the actual phrased questions. It is designed to help item writers prepare questions in the Electric Power Engineering Discipline Exam as well as a study guide for the examinees.

2. Exam Structure:

2.1 Exam Type

The exam is initially paper-based with questions being a combination of multiple- choice questions (MCQ) and essays.

2.2 Exam Organization

The exam will be conducted in two sessions during one day. The duration of the first session is 2.5 hours while the second section is 4 hours long. There is one-hour break between the two sessions.

2.2.1. Session #1

The first session is the common part to be taken by all the examinees from all disciplines. This part includes seven topics: (Ethics – Professionalism - Laws for Professional Practice, Professional Laws and Regulation - Environment and Natural Resources - Engineering Management - Engineering Economics - Health, Safety & Security (HSS)).

The total duration of this session is 2.5 hours and the total number of questions is 30 MCQ and 2 essays.

2.2.2. Session #2

The second session is the Discipline Part. The following engineering disciplines are considered:

Code	Discipline
STE	Structural Engineering
GTE	Geotechnical Engineering
TRE	Transportation Engineering
WREE	Water Resources and Environmental Engineering
PE	Power Engineering
HVAC	Heating, Ventilation, and Air Conditioning (HVAC) and Refrigeration Engineering
TFSE	Thermal and Fluids Systems Engineering
CHE	Chemical Engineering
FPE	Fire Protection Engineering
ARCH	Architecture

The total duration of this session is 4 hours and the total number of questions is 30 MCQs and 4 essays. The examinee must answer all the MCQs and two essays out of four.

2.3 Eligibility for the Exam

The eligibility to register for the exam is according to the Saudi Council of Engineers (SCE) rules and regulations.

2.4 Grades

Each part (common part and discipline part) carries a total grade of 100. The MCQs carry a grade of 60% while the essays carry a grade of 40%. Each MCQ has 4 choices for the answer. There is no negative marking for wrong answers.

2.5 Passing Rules

- The eligible candidate must take in his/her first sitting the two exam parts (common part and discipline part).
- In order to pass the exam, the candidate must obtain a grade of 60% or above in each part of the exam.
- If the candidate fails both parts of the exam (by receiving in each part a grade less than 60%), he/she can take the two parts of the exam but only when one full year has passed.
- If the candidate fails only one part of the exam (common part or discipline part), he/she must repeat only the part he/she failed, but he/she must pass this part within one year.
- If a year passed and the candidate did not succeed in passing the part he/she failed, then he/she has to take both parts of the exam.

2.6 Exam Rules

- No printed or electronic material is allowed during the exam. All necessary reference materials will be provided by NCA
- Calculators approved by NCA are allowed.
- Comprehensive exam rules will be provided by the examination authority, NCA, in a separate manual.

3. Table of Specifications for Electric Power Engineering Exam:

Major Area	Multiple Choice Questions (MCQs)		Essay Questions	Engineering Standard
	% of Test	# Q		
1. General Electric Power	13.3	4	--	PWRE-T1
2. Electric Circuit Analysis	13.3	4	--	PWRE-T2
3. Electric Machines	16.7	5	4	PWRE-T3
4. Power Electronics	13.3	4		PWRE-T4
5. Power System Operations	16.7	5		PWRE-T5
6. Power System Protection	13.3	4		PWRE-T6
7. Renewable Energy	13.3	4		PWRE-T7
Total	100%	30	Choose 2 out of 4	

4. Standards for Architecture:

The Engineering Standards for the Electric Power Engineering Discipline are structured based on the following 7 applied topics:

PWRE -T1	General Electric Power.
PWRE -T2	Electric Circuit Analysis.
PWRE -T3	Electric Machines.
PWRE -T4	Power Electronics.
PWRE -T5	Power System Operations.
PWRE -T6	Power System Protection.
PWRE -T7	Renewable Energy.

The above topics cover all the branches of the electric power engineering and the most important practical experiences in this field. Each of these topics has a number of indicators that ensure that the engineer has the necessary experience to work in electric power engineering area. These areas are mainly on electric machines, power electronics, power system engineering, and renewable energy applications that are summarized in the following.

PWRE -T1: General Electric Power

General electric power consists of the topics that all electric power engineers should be familiar with. These topics contain many general indicators like Electric Safety and Hazard Protection, General Power Engineering, and National/international Electric Code that are shown in the following:

PWRE -T1.1 Electric Safety and Hazard Protection

PWRE-T1.1.1	Understand how to check the efficiency and adequacy of safety equipment/grounding systems, and identify the suitable personal protective equipment for different operating voltages.
PWRE-T1.1.2	Recognize the risks of different operating voltage levels and the required actions in case of electric hazard emergency.
PWRE-T1.1.3	Revise the standards, legislations and guidelines for electrical safety in the workplace.
PWRE-T1.1.4	Understand the concept of arc flash and its precaution.

PWRE-T1.1.5 Understand electric safety aspects of large-scale solar PV power plants and prevention of electric arc in DC circuits.

PWRE-T1.1.6 Understand the levels of currents associated with different levels of shock hazards and recognize the situations which can result in shock hazards.

PWRE -T1.2 General Power Engineering

PWRE-T1.2.1 Practice how to measure insulation resistance of a given apparatus and know the limits of insulation resistance of different equipment.

PWRE-T1.2.2 Recognize different insulation tests such as dielectric absorption ratio, step voltage test, and spot-reading test, etc. and recognize the difference between AC and DC resistance tests.

PWRE-T1.2.3 Understand the factors that affect the grounding resistance, and methods of measuring its value.

PWRE-T1.2.4 Recognize the main functions of major equipment used in the generation, transmission, and distribution of electric power.

PWRE-T1.2.5 Recognize the practical energy management techniques for national, utility, community, household scales.

PWRE-T1.2.6 Understand the installation requirements for rooftop solar PV systems and economic calculations.

PWRE-T1.2.7 Design of illumination, lighting systems, and energy efficient lighting with LEDs.

PWRE-T1.2.8 Understand the basics of engineering economics.

PWRE-T1.2.9 Understand how to calculate the electricity tariff for residential and commercial buildings with and without solar PV installations.

PWRE-T1.2.10 Understand the electric system structure in a deregulated market environment.

PWRE -T1.3 National/international Electric Code

PWRE-T1.3.1 Recognize the Saudi Electrical Code SBC 401, the standard protection against electric shock and lightning, standard for wiring systems, isolation, grounding, and power factor improvement.

PWRE-T1.3.2 Recognize the National Electrical Safety Code (ANSI C2, NESC), standards for electric power supply, and the required specifications and standard for overhead lines and equipment.

PWRE-T1.3.3 Understand the effects of current and voltage harmonics in electric power distribution systems and review IEEE 519 standards.

PWRE-T1.3.4 Understand IEEE 1547 and IEC 61727 standards for interconnecting renewable energy systems to electric grid.

PWRE-T1.3.5 Recognize the Saudi grid code.

PWRE -T2: Electric Circuit Analysis

Engineers in all electric power engineering branches should be familiar with electric circuits. There are two main topics in electric circuits: DC circuits and AC circuits. The practical engineering problems are based on the electric circuit fundamentals. The indicators of electric circuits are shown in the following:

PWRE -T2.1 DC Circuits

PWRE-T2.1.1 Analyze series-parallel DC circuits, using circuit analysis methods such as Kirchhoff's current and voltage laws, Nodal, loop methods.

PWRE-T2.1.2 Analyze given circuit to find Thevenin's and Norton's equivalents and apply maximum power transfer theorem.

PWRE-T2.1.3 Analyze the transient response of first order DC circuits.

PWRE -T2.2 AC Circuits

PWRE-T2.2.1 Analyze series-parallel AC circuits, using circuit analysis methods such as Kirchhoff's current and voltage laws, node and loop methods, Laplace transform.

PWRE-T2.2.2 Analyze a given circuit to find Thevenin's and Norton's equivalents and apply maximum power transfer theorem and superposition theorems in AC circuits.

PWRE-T2.2.3 Analyze frequency response & resonance, filter circuits and two-port networks.

PWRE-T2.2.4 Understand the concept of independent and dependent power sources and conversion of voltage & current sources.

PWRE-T2.2.5 Understand sinusoidal sources, wye-delta connections and the concept of phasors in circuit analysis.

PWRE-T2.2.6 Understand the concept of magnetically coupled circuits, ideal transformer and ideal operational amplifier circuits.

PWRE-T2.2.7 Analyze power factor improvement techniques for single/three-phase AC circuits.

PWRE-T2.2.8 Understand how to measure power factor, electric power (watts) in AC circuits with harmonic currents drawn by nonlinear loads.

PWRE-T2.2.9 Understand the techniques used for power measurement in three-phase circuits.

PWRE-T2.2.10 Understand the symmetrical components transformation, the physical meaning of positive, negative, and zero sequence components and circuits.

PWRE-T2.2.11 Understand the three-phase connection arrangements and basic relations among phase and line quantities of voltage and currents for each type.

PWRE -T3: Electric Machines

Electrical machines topic is one of the most important branches of electric power engineering since most of generation of electric energy comes from electric machines. Moreover, most of big loads are kinds of electric machines. Also, the step-up transformers at the terminals of generation substation and step down loads at the load sides are one of the electric machines. So, it is essential for all electrical power engineering branches to be familiar with electric machines with different levels. The electric machines indicators are listed in the following:

PWRE -T3.1 Single-Phase Power and Instrument Transformers

PWRE-T3.1.1 Understand the exact and approximate equivalent circuits and the tests required to determine the equivalent circuit parameters of power transformer.

PWRE-T3.1.2 Analyze transformer voltage regulation, losses and efficiency.

PWRE-T3.1.3 Recognize single-phase autotransformer connections, and compare it with single-phase two winding transformer in terms of voltage regulation and efficiency.

PWRE-T3.1.4 Recognize voltage and current instrument transformers construction, operations, applications, precautions, and burden.

PWRE-T3.1.5 Understand the effect of current harmonics in electric measurements.

PWRE-T3.1.6 Understand the coupling capacitor voltage transformer (CCVT).

PWRE-T3.2 Three-phase Power Transformers

PWRE-T3.2.1 Recognize the different connections and construction of three-phase transformer.

PWRE-T3.2.2 Recognize transformer cooling system and maintenance of power transformers.

PWRE-T3.2.3 Understand the inrush current and its consequences, the factors that affect its value, and how to remedy the effect of inrush current of transformer.

PWRE-T3.2.4 Understand K-factor transformers.

PWRE-T3.2.5 Recognize 3 phase autotransformer connections, and compare it with 3-phase two winding transformer in terms of voltage regulation and efficiency.

PWRE-T3.2.6 Understand the concept of parallel operation of transformers and their pre-conditions.

PWRE-T3.3 DC Machines Operations and Applications

PWRE-T3.3.1 Understand the construction, connections, operation, and applications of DC machines.

PWRE-T3.3.2 Recognize the power flow, losses, and efficiency of DC machines.

PWRE-T3.3.3 Understand the starting techniques of DC motors.

PWRE-T3.3.4 Recognize the armature reaction of DC machines and methods of remedy this problem using brush shift, inter-poles and compensating windings.

PWRE-T3.3.5 Understand the torque-speed characteristics of the DC series, shunt & compound motors.

PWRE-T3.3.6 Recognize the methods for DC motor speed control.

PWRE-T3.4 Synchronous Machines

PWRE-T3.4.1 Recognize the construction, connections, operation and applications of synchronous machines.

PWRE-T3.4.2 Recognize the effect of load current, power factor and field current variations on the performance of stand-alone synchronous generators.

PWRE-T3.4.3 Recognize the requirements for synchronization of AC generators and how to perform the synchronization manually and automatically in the field.

PWRE-T3.4.4 Understand the house curve and recognize how to use it to share the power between synchronous generators and electric utility.

PWRE-T3.4.5 Recognize the power, efficiency, torque, speed, and voltage regulation of synchronous generators.

PWRE-T3.4.6 Understand the control requirements of large synchronous generators.

PWRE-T3.4.7 Describe the parallel operation techniques of synchronous generators.

PWRE-T3.4.8 Understand the equivalent circuit and torque-speed characteristic of a synchronous motor.

PWRE-T3.4.9 Understand the effect of load, field current and power factor correction of a synchronous motor.

PWRE-T3.4.10 Recognize the steady state stability limit of synchronous machines.

PWRE-T3.4.11 Recognize the V-curve of synchronous motors.

PWRE-T3.5 Single/Three-phase Induction Machines

PWRE-T3.5.1 Understand single/three-phase induction machines constructions, operations, equivalent circuit and motor torque-speed characteristics.

PWRE-T3.5.2 Recognize starting methods for single/three-phase induction motors.

PWRE-T3.5.3 Recognize the speed control methods of induction motors.

PWRE-T3.6 Special Motors

PWRE-T3.6.1 Understand the construction, operation, applications of the universal motor, and hysteresis motor.

PWRE-T3.6.2 Recognize the construction, operation, and applications of reluctance motors, stepper motors, and brushless DC motors.

PWRE-T4: Power Electronics

Power electronics branch is a very important branch for all electric power engineers where it is used in integrating renewable energy sources with electric utility and excitation systems of conventional power plant generators and most of loads like motor drives and other loads. Power electronics converters are counted as nonlinear loads that inject harmonics to the power system which has bad effects on the performance of the power system. Electric power engineers should be familiar with power electronics converters and its effects on the power system. The indicators of power electronics converters are listed in the following:

PWRE-T4.1 Switches Characteristics

PWRE-T4.1.1 Understand the construction, operating principle and practical applications principles of diodes, thyristor, transistor, triac, IGBT, MOSFET, Silicon Carbide (SiC), GaN transistors and other modern power electronics switches.

PWRE-T4.2 Uncontrolled Single/Three-phase AC-DC Converters

PWRE-T4.2.1 Understand the applications of single/three-phase full and half wave uncontrolled AC-DC converters.

PWRE-T4.2.2 Recognize the harmonics of supply current of single/three-phase uncontrolled rectifiers and techniques to reduce the harmonics.

PWRE-T4.2.3 Understand the effects of voltage sag/swell on AC-DC converters.

PWRE-T4.3 Controlled/ Semi-controlled Single/Three-phase Converters

PWRE-T4.3.1 Understand applications of single/three-phase controlled/semi-controlled converters as rectifier and inverter.

PWRE-T4.3.2 Understand the applications of three-phase controlled converters in motor drives, wind energy systems, and induction furnaces applications.

PWRE-T4.3.3 Assess the harmonics of supply current of single/three-phase controlled/semi-controlled converters and methods of harmonic reductions.

PWRE-T4.3.4 Assess the methods of harmonic reduction in single/three-phase controlled converters.

PWRE-T4.3.5 Understand the four quadrant operation of SCR converters and their commutation failure.

PWRE-T4.4 DC-DC Converters

PWRE-T4.4.1 Understand the circuit, operations, and applications of buck, boost, buck/boost, cuck and fly-back, forward and full-bridge converters.

PWRE-T4.4.2 Design the components of DC-DC converters with and without high frequency transformer isolation.

PWRE-T4.4.3 Understand zero voltage and zero current switching techniques.

PWRE-T4.5 Pulse-Width Modulation Converters

PWRE-T4.5.1 Understand the circuits and operations of unipolar/bipolar single phase pulse-width modulation converters.

PWRE-T4.5.2 Understand the circuits, operations, harmonics and applications of sine-wave three-phase pulse-width modulation converters.

PWRE-T4.5.3 Understand space vector modulation methods.

PWRE-T4.6 Motor Drives

PWRE-T4.6.1 Assess the types and operation of single/three-phase motor drives.

PWRE-T4.6.2 Recognize how to control the speed and torque of single/three-phase AC motors using motor drives.

PWRE-T4.6.3 Understand the practical applications of three-phase induction motor at below and above the rated speeds.

PWRE-T4.7 AC-AC Converters Applications

PWRE-T4.7.1 Understand the practical applications of single/three-phase AC-AC converters as a voltage controller.

PWRE-T4.7.2 Understand the practical applications of single/three -phase AC-AC converters as a motor soft starter.

PWRE-T4.7.3 Understand the applications of static/dynamic VAR compensators.

PWRE-T4.8 FACTS Devices

PWRE-T4.8.1 Recognize the main functions of various FACTS devices.

PWRE-T4.8.2 Understand the applications of FACTS devices in power systems.

PWRE-T4.8.3 Design the suitable FACTS devices for correcting power system local/global problems.

PWRE-T4.9 High Voltage DC (HVDC) Transmission

PWRE-T4.9.1 Recognize the application of power electronic devices for HVDC transmission of electricity.

PWRE-T4.9.2 Understand the advantages of HVDC transmission against HVAC transmission for bulk energy transmission over large distances.

PWRE-T5: Power System Operations

Power system operations topic is a very important topic to all engineers working in power systems generation, transmission and distribution. Moreover, all engineers working in the distributed generation, micro grids, and smart grid systems should be familiar with this topic. This topic is related to all branches in the power system operations like the Utility AC Power System Architecture, Cables/Transmission Lines, Power Factor Correction and Voltage Support, Power Quality, and Grounding Practices. The indicators of this topic are listed as shown in the following:

PWRE-T5.1 Utility AC Power System Architecture

PWRE-T5.1.1 Recognize the power system parts from generation to distribution.

PWRE-T5.1.2 Understand the practical meaning of voltage regulation and support, power quality, distributed generation, power flow and power system stability.

PWRE-T5.1.3 Recognize the construction, performance and characteristics of air insulated substations (AIS) and gas insulated substations (GIS).

PWRE-T5.1.4 Understand the characteristics of SF_6 gas and its practical applications in circuit breakers and other elements of GIS.

PWRE-T5.1.5 Understand the substation switchgears for single chamber and double chamber and the procedures required for safe maintenance of substations.

PWRE-T5.1.6 Understand the function and operations of equipment in substation such as circuit breakers, busbars, fuses, measuring instruments, and disconnectors.

PWRE-T5.1.7 Recognize the arrangement, performance characteristics and operation of high voltage DC transmission systems.

PWRE-T5.1.8 Understand the optimal sizing and placement of distributed generation.

PWRE-T5.1.9 Understand the concept of power system modeling, bus admittance matrix and bus impedance matrix.

PWRE-T5.1.10 Understand the different load flow analysis techniques like Gauss-Seidel, Newton Raphson and Fast-Decoupled methods.

PWRE-T5.1.11 Recognize the solution of optimal power flow problem.

PWRE-T5.1.12 Recognize different faults in power systems and short circuit analysis.

PWRE-T5.1.13 Understand power system stability and methods for enhancement.

PWRE-T5.2 Cables/Transmission Lines

PWRE-T5.2.1 Understand the types and the characteristics of underground cables and overhead transmission lines.

PWRE-T5.2.2 Understand the significance of Skin Effect in cables/transmission lines and techniques to minimize it.

PWRE-T5.2.3 Recognize the meaning of reflection coefficient, surface roughness, R, C and L parameters for cables/transmission lines.

PWRE-T5.2.4 Understand how to measure the dielectric resistance and capacitance of cables.

PWRE-T5.2.5 Understand the testing procedures for cables and transmission lines and how to maintain and fix them.

PWRE-T5.2.6 Understand the techniques used for identifying the fault locations in cables and transmission lines.

PWRE-T5.2.7 Analyze sag and tension in the overhead transmission lines.

PWRE-T5.2.8 Understand maximum power flow and the line loadability.

PWRE-T5.3 Power Factor Correction and Voltage Support

PWRE-T5.3.1 Understand how to determine the required capacitor value for power factor corrections and its merits on current, voltage and tariff.

PWRE-T5.3.2 Recognize the function of shunt reactors and series capacitor compensation.

PWRE-T5.3.3 Understand the component of static VAR compensation system and its function.

PWRE-T5.3.4 Recognize the procedures of testing of capacitor banks.

PWRE-T5.4 Power Quality

PWRE-T5.4.1 Understand the definition and significance of voltage sag/swell, total harmonic distortion.

PWRE-T5.4.2 Recognize the IEEE 519 and IEC 61000 family of standards for providing the limits of power quality issues.

PWRE-T5.4.3 Understand the techniques used to reduce the harmonic contents in power system.

PWRE-T5.4.4 Understand power system stability.

PWRE-T5.5 Grounding Practices

PWRE-T5.5.1 Understand the practical design and arrangements of grounding of transmission lines, substations and consumer facilities.

PWRE-T5.5.2 Recognize national and international standard codes for grounding.

PWRE-T5.5.3 Recognize the effect of high grounding resistance on safety and protection.

PWRE-T5.5.4 Understand the procedures required for grounding resistance measurement.

PWRE-T6: Power System Operations

All parts of the power system need certain kind of protection to protect them from any abnormal conditions. This topic is very important to all engineers working in the electric power discipline to be able to understand, study, and design the protection system of different components of the power system with different levels. The indicators of the power system protection are shown in the following:

PWRE-T6.1 Faults, Types and Effects

PWRE-T6.1.1 Recognize the fault types and their effects on the power system.

PWRE-T6.1.2 Understand the frequency of occurrence of each type of faults and the best action required to remedy their adverse effects on power system.

PWRE-T6.2 Protection System Devices

PWRE-T6.2.1 Understand types of fuse and its replacement ways, and its standard (IEC 60269) and understand the differences between fuse and circuit breaker.

PWRE-T6.2.2 Understand the construction, function, types, operation and maintenance of circuit breakers.

PWRE-T6.2.3 Understand current/voltage transformer construction, operation, transformation ratio, phase angle error, burden and accuracy, safety aspects in dealing with it.

PWRE-T6.2.4 Recognize protection and metering classes.

PWRE-T6.2.5 Understand metrosil and the nonlinear resistors.

PWRE-T6.3 Relays

PWRE-T6.3.1 Understand the function, construction and types (e.g., differential, distance, under voltage, pilot) of relays and revise the differences between solid state and electromechanical relays.

PWRE-T6.3.2 Understand the coordination between over current relays in radial systems.

PWRE-T6.3.3 Understand the function, construction and types of reclosers and applications of automatic reclosers and sectionalizers.

PWRE-T6.3.4 Understand the protection zones.

PWRE-T6.3.5 Understand the stability and sensitivity tests.

PWRE-T6.4 Transformer Protection

PWRE-T6.4.1 Understand the neutral earthing function and limits of neutral earthing impedance of the transformers.

PWRE-T6.4.2 Recognize the construction, and operation of transformer differential protection.

PWRE-T6.4.3 Recognize the function, construction and operation of Buchholz relay.

PWRE-T6.4.4 Understand the function and construction of the transformer's pressure relay, the transformer's over current relay, and the directional earth fault protection.

PWRE-T6.4.5 Understand and describe the Ferro-resonance phenomena and how to remedy its effect.

PWRE-T6.5 Motor Protection

PWRE-T6.5.1 Recognize the importance and methods of AC motor protection against over current, under voltage, ground faults and temperature rise.

PWRE-T6.5.2 Understand the techniques for motor start and stall detection.

PWRE-T6.6 Generator Protection

PWRE-T6.6.1 Recognize the internal/external generator faults and protection needs.

PWRE-T6.6.2 Understand the over current/overvoltage protection, unbalance load protection, rotor fault protection, reverse power protection, excitation current protection, field current suppression protection, and loss of synchronization protection of AC generators.

PWRE-T7: Renewable Energy

Due to the limitations of fossil fuels needed for power plants and the increase of energy needed for residential and industrial loads, the renewable energy became an important source of energy in power system generation mix. There are two important sources of renewable energy in KSA and many other countries which are solar and wind energies. All engineers in electric power discipline should be familiar with these two sources. Due to the intermittent nature of these two sources there is the need for storage system to store the extra energy and feed the load with the required energy when the generation from these energy sources are not satisfying the needs. The indicators of the renewable energy systems are shown in the following:

PWRE-T7.1 Solar Energy

PWRE-T7.1.1 Understand types, construction, and operating principals of solar thermal systems.

PWRE-T7.1.2 Recognize the construction, design, operation, sizing and characteristics of the photovoltaic (PV) energy systems.

PWRE-T7.1.3 Recognize the construction, design, operation, sizing and characteristics of the CSP energy systems.

PWRE-T7.1.4 Understand the maximum power point tracking techniques of PV systems under normal and partial shading conditions.

PWRE-T7.1.5 Design the battery size suitable for applications with PV systems.

PWRE-T7.1.6 Understand the integration challenges of solar energy systems with electric utility.

PWRE-T7.2 Wind Power

PWRE-T7.2.1 Recognize the variation of power with wind speed and the variation of speed with height.

PWRE-T7.2.2 Understand the construction, operation and characteristics of horizontal/vertical wind turbines and their merits/demerits.

PWRE-T7.2.3 Design the required number of wind turbines to feed certain load, and how to select the best wind turbine that matches the site wind speed and how these can reflect on the cost of energy from wind energy systems.

PWRE-T7.2.4 Understand the operation of a variable speed wind turbine system.

PWRE-T7.2.5 Understand direct coupling and doubly fed induction generators of wind turbines with electric utility.

PWRE-T7.2.6 Understand the integration challenges of wind energy systems with electric utility.

PWRE-T7.3 Energy Storage

PWRE-T7.3.1 Understand the principle of energy storage using hydroelectricity, flywheel, and compressed air energy storage systems.

PWRE-T7.3.2 Recognize the idea behind using the ultra-capacitors, and superconducting materials and the challenges in their applications in energy storage systems.

PWRE-T7.3.3 Understand the basic differences between types of batteries.

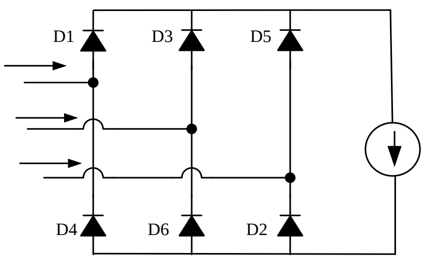
PWRE-T7.3.4 Understand the requirement for battery to be used as energy storage in renewable energy applications.

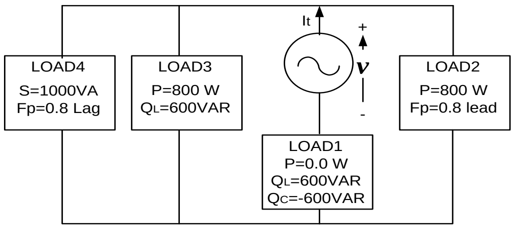
PWRE-T7.3.5 Recognize the aging, abuse and capacity degradation tests of battery systems under different operating conditions.

PWRE-T7.3.6 Understand how to use hydrogen as energy storage medium and the storage techniques and challenges.

5. Sample Questions Table

Q. No.	Major Area	Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min.)	Supplied Reference
1	PWRE-T1. General Electric Power PWRE-T1.1 Electric Safety and Hazard Protection	PWRE-T1.1.2	Overcharging lead-acid or alkali batteries is very dangerous because it produces one of these gases: (a) O_2 gas (b) SF_6 gas (c) CO_2 gas (d) H_2 gas	(d)	2	None
2	PWRE-T1. General Electric Power PWRE-T1.1 General Power Engineering	PWRE-T1.2.9	A factory has a 100 kVA transformer works at 98% full load efficiency at unity power factor is used to feed 100kVA at 0.8 lagging power factor load for 8 hours/day and 50 kVA at unity power factor for 8 hours/day and the transformer is connected to the line without load for 8 hours/day. The cost of electricity is SR 0.20/kWh. Assume the constant and variable losses are equal. What is the yearly cost of losses of the transformer? (a) SR 1881 (b) SR 2086 (c) SR 3278 (d) SR 3575	(a)	4	None
3	PWRE-T1. General Electric Power PWRE-T1.3 National/international Electric Code	PWRE-T1.3.3	According to IEEE-519-1992 standard, the maximum allowed total harmonic distortion in current for loads connected to 69 kV bus-bar with short circuit current equal 30 times of the connected load is: (a) 5% (b) 8% (c) 12% (d) 15%	(b)	2	None
4	PWRE-T3: Electric Machines PWRE-T3.1 Single-Phase Power and Instrument Transformers	PWRE-T3.1.2	A factory has 1000 kVA transformer with 3% impedance. The loads are increased and the owner decided to parallel connect a new transformer with 2000 kVA and 4% impedance. The maximum kVA that can these two transformers feed is: (a) 3000 kVA (b) 2500 kVA (c) 2250 kVA (d) 2000 kVA	(b)	3	None

Q. No.	Major Area	Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min.)	Supplied Reference
5	**PWRE-T3: Electric Machines** **PWRE-T3.2 Three-phase Power Transformers**	PWRE-T3.2.3	Sludging problem that occurs in the transformer is due to: a) Oil leak from the tank b) Moisture increase in the oil c) Decomposition of the oil d) Dust accumulated in the tank	(c)	2	None
6	**PWRE-T3: Electric Machines** **PWRE-T3.3 DC machines operations and applications**	PWRE-T3.3.5	Increasing the load of differential compound DC motor will: a) increase its speed. b) not change motor speed. c) reduce its speed. d) reduce the load current.	(a)	2	None
7	**PWRE-T3: Electric Machines** **PWRE-T3.4 Synchronous Machine**	PWRE-T3.4.2	Increasing the load current of synchronous generator operating alone feeding lagging power factor load; a) will reduce the terminal voltage and torque angle. b) will increase the terminal voltage and reduce the torque angle. c) will increase the terminal voltage and torque angle. d) will reduce the terminal voltage and increase torque angle.	(d)	2	None
8	**PWRE-T4 Power Electronics** **PWRE-T4.2 Uncontrolled single/three-phase AC-DC converters**	PWRE-T4.2.2	For three-phase uncontrolled rectifier with pure DC current load without source inductance supplied from balanced pure sine-wave AC supply as shown in figure, the THD of supply current is about: a) 14 % b) 22% c) 31% d) 45 %. 	(c)	4	None

Q. No.	Major Area	Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min.)	Supplied Reference
9	**PWRE-T4 Power Electronics** **PWRE-T4.6 Motor Drives**	PWRE-T4.6.2	A three-phase PWM inverter is required to drive three phase 4 poles induction motor at 1300 rpm at slip s=0.04, the frequency of the control waveform is about: a) 50 Hz b) 60 Hz c) 43.3 Hz d) 45.1Hz	(d)	3	None
10	**PWRE-T5.1 Utility AC** **Power System Architecture**	PWRE-T5.1.1	Thermal power plant has many components; which component causes the highest energy losses? a) Transformer b) Steam turbine c) Condenser d) AC Generator (Alternator)	(c)	2	None
11	**PWRE-T5: Power System Operations** **PWRE-T5.3 Power Factor Correction and Voltage Support**	PWRE-T5.3.1	For the circuit shown in the following figure, $v = 100\sqrt{2}\cos(1000t)$, the capacitance value of the required capacitor should be connected in parallel with supply to have a unity power factor seen by the supply is:  a) 40 μF b) 50 μF c) 60 μF d) 70 μF	(c)	4	None
Essay (1)	**PWRE-T3: Electric Machines** **PWRE-T3.1 Single-Phase Power and Instrument Transformers**	PWRE-T3.1.2	What effect does armature reaction have on the torque-speed characteristics of a shunt DC motor? Can the effect of armature reaction be serious? What can be done to remedy this problem?		30	None

Q. No.	Major Area	Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min.)	Supplied Reference
Essay (2)	**PWRE-T3: Electric Machines** **PWRE-T3.2 Three-phase Power Transformers**	PWRE-T3.2.6	What is the meaning of transformer polarity? Explain and draw how to determine it in the lab? And why it is important in parallel operation of single-phase transformers?		30	None

6. Solutions of Sample of Questions

Multiple Choice Questions (MCQs)

Question # 1

Overcharging lead-acid or alkali batteries are very dangerous because it produces one of these gases:

a. O_2 gas

b. SF_6 gas

c. CO_2 gas

d. H_2 gas

Answer:

Overcharging the lead acid batteries will increase the generation of H_2 gas which increase its concentration around the place of the battery. If the concentration of H_2 became greater than 4% it may cause explosion with any spark.

Answer is: (d)

Question # 2

A factory has a 100 kVA transformer works at 98% full load efficiency at unity power factor is used to feed 100 kVA at 0.8 lagging power factor load for 8 hours/day and 50 kVA at unity power factor for 8 hours/day and the transformer is connected to the line without load for 8 hours/day. The cost of electricity is SR 0.20/kWh. Assume the constant ad variable losses are equal. What is the yearly cost of losses of the transformer?

a. SR 1881

b. SR 2086

c. SR 3278

d. SR 3575

Answer:

$$\text{Efficiency} = \frac{\text{Output Power}}{\text{Input Power}}$$

Efficiency=100/(100+PC+PV)=0.98

PC+PVF=100/0.98-100=2.041kW

In case of the constant ad variable losses are equal, then PC=PVF=1.0205 kW

Losses per year=365*losses per day

Losses per year=365*(2.041*8+1.0205*(1+1/4)*8+1.0205*8)=9405.183kWh

The cost of losses per year=9405.183*0.2=SR 1881

Where, PC=Constant losses

PVF =Variable losses at full load

Answer is: (a)

Question # 3

According to IEEE-519-1992 standard, the maximum allowed total harmonic distortion in current for loads connected to 69 kV busbar with short circuit current equal 30 times of the connected load is:

a. 5%

b. 8%

c. 12%

d. 15%

Answer:

From the IEEE 519 standard, the answer is (b) 8%

Table (1.1) IEEE 519-1992 current distortion limits for general distribution systems (120 to 69kV) the maximum harmonic current distortion in percent of I_L

Individual Harmonic order (Odd Harmonics)						
I_{SC} / I_L	n<11	11≤n<17	17≤n<23	23≤n<35	35≤ n<	TDD
<20	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

Where; TDD (Total Demand Distortion) = $\frac{100}{I_{ML}}\sqrt{\sum_{n=2}^{\infty} I_n^2}$,

Answer is: (b)

Question # 4

A factory has 1000 kVA transformer with 3% impedance. The loads are increased and the owner decided to parallel connect a new transformer with 2000 kVA and 4% impedance. The maximum kVA that can these two transformers feed is:

a. 3000 kVA
b. 2500 kVA
c. 2250 kVA
d. 2000 kVA

Answer:

kVA rating of each transformer is inversely proportional to its internal impedance. The impedance of second transformer related to the kVA of first transformer is 0.5*4%=2%

If S_1(max)=1000 kVA, then S_2 (max)=3/2*1000=1500 kVA

Then, the two transformers can feed 1000+1500=2500 kVA

Where S_1(max) and S_2(max) are the maximum kVA for transformer #1 and #2, respectively..

Question # 5

Sludging problem occurs in the transformer is due to:

a. Oil leak from the tank
b. Moisture increase in the oil
c. Decomposition of the oil
d. Dust accumulated in the tank

Answer:

(c) Decomposition of the oil

Question # 6

Increasing the load of differential compound DC motor will:

a. increase its speed.
b. not change motor speed.
c. reduce its speed.
d. reduce the load current.

Answer:

(a) increase its speed.

Question # 7

Increasing the load current of synchronous generator operating alone feeding lagging power factor load:

a. will reduce the terminal voltage and torque angle.
b. will increase the terminal voltage and reduce the torque angle.
c. will increase the terminal voltage and torque angle.
d. will reduce the terminal voltage and increase torque angle.

Answer:

(d) will reduce the terminal voltage and increase torque angle.

Question # 8

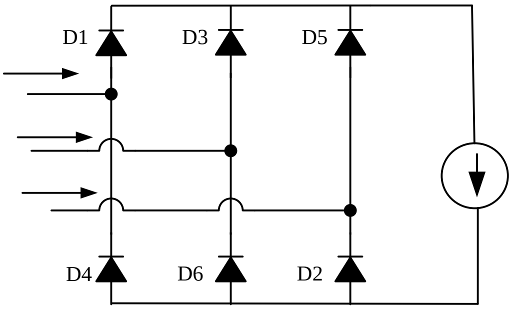
For three-phase uncontrolled rectifier with pure DC current load <u>without</u> source inductance supplied from balanced pure sine-wave AC supply as shown in figure, the THD of supply current is about

(a) 14 %

(b) 22%

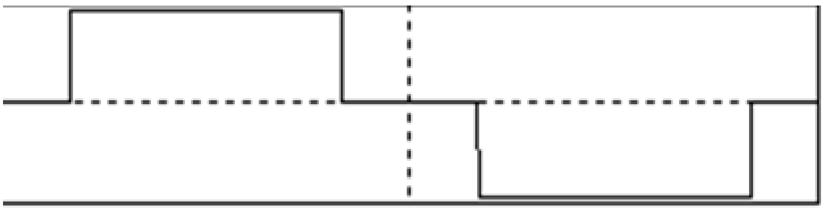
(c) 31%

(d) 45 %.



Answer:

The RMS of supply current is shown in this figure is equal to $I_S = \sqrt{\frac{2}{3}} I_o$, where Io is the DC load current.



As it is clear from supply current, it is odd function, then a_n=0, and

$$b_n = \frac{2}{\pi} \int_{\pi/6}^{5\pi/6} I_o * \sin n\omega t \; d\omega t$$

$$= \frac{2 I_o}{n\pi} [-\cos n\omega t]_{\pi/6}^{5\pi/6}$$

$$b_1 = \frac{2 I_o}{\pi} \sqrt{3},$$

Then, the RMS of fundamental current is $I_{S1} = \frac{b_1}{\sqrt{2}} = \frac{\sqrt{2} * \sqrt{3}}{\pi} I_o$

Then, $$THD(I_s(t)) = \sqrt{\left(\frac{I_S}{I_{S1}}\right)^2 - 1} = \sqrt{\frac{2/3}{2*3/\pi^2} - 1} = 31.01\%$$

Where I_s is the RMS of the supply current.

So, the answer is (c) 31%

Question # 9

Three-phase PWM inverter is required to drive three phase 4 poles induction motor at 1300 rpm at slip s=0.04, the frequency of the control waveform is about:

(a) 50 Hz

(b) 60 Hz

(c) 43.3 Hz

(d) 45.1Hz

Answer:

$$n_s = \frac{n}{(1-s)} = \frac{1300}{1-0.04} = 1354.17\ rpm$$

Where, n_s is the synchronous speed, n is the rotational speed, and s is the slip of the motor.

Then, the frequency of the control waveform is: $$f_1 = \frac{P * n_s}{120} = \frac{4*1354.17}{120} = 45.14\ Hz$$

Answer (d) 45.1 Hz

Question # 10

Thermal power plant has many components; which component causes highest energy losses?

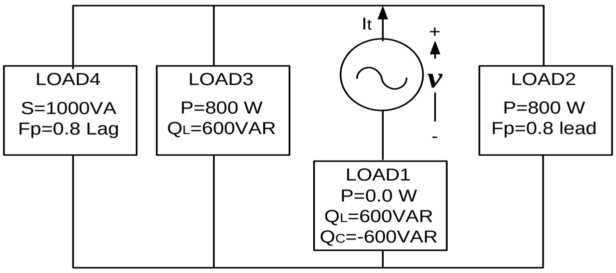
a. Transformer
b. Steam turbine
c. Condenser
d. AC Generator (Alternator)

Answer:

(c) Condenser

Question # 11

For the circuit shown in the following figure, $v = 100\sqrt{2}\cos(1000t)$, The capacitance value of the required capacitor should be connected in parallel with supply to have a unity power factor seen by the supply is:



a. 40 μF
b. 50 μF
c. 60 μF
d. 70 μF

Answer: The total reactive power is the summation of the reactive power for each load,

Q_L=600-600-800/0.8*sin($\cos^{-1}$(0.8))+600+1000*sin($\cos^{-1}$(0.8))=600VAR

C=QL/wV^2=600/(1000(100)^2)=60μF

Answer is (c) 60 μF

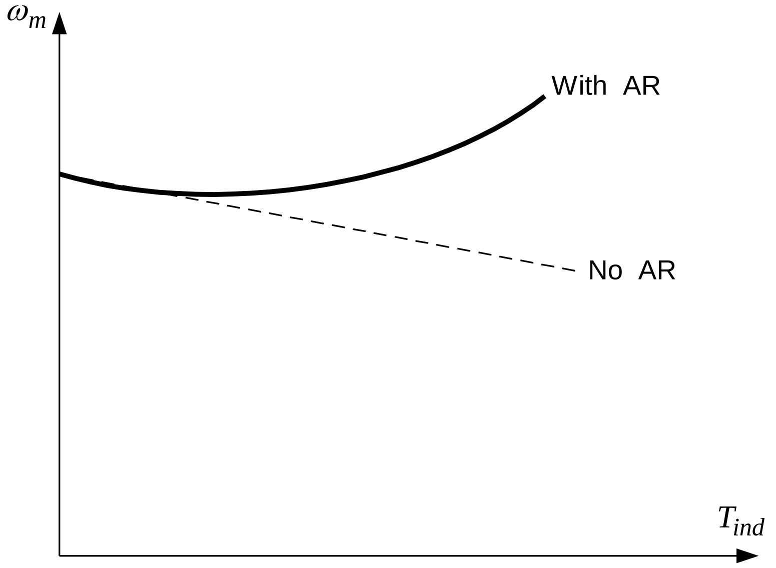
Essay Question

Essay # 1

What effect does armature reaction have on the torque-speed characteristics of a shunt DC motor? Can the effect of armature reaction be serious? What can be done to remedy this problem?

Answer:

If the load increased of shunt DC motor, the flux generated from armature conductors reduces its main flux. The effect of a flux reduction is to increase the motor's speed characteristics as shown in the following figure.



Torque-speed characteristics of a shunt DC motor.

Yes, the effect of armature reaction can be serious on shunt DC motor because as we explain before when the flux in a motor is decreased, its speed increases. Consequently, increasing the speed of a motor will increase its load, resulting in more flux weakening. It is possible for some shunt DC motors to reach a runaway condition as a result of flux weakening which can destroy the motor.

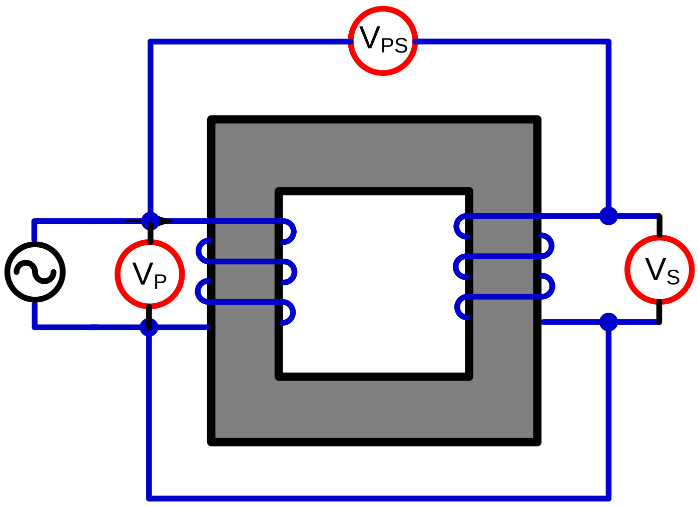
Essay # 2

What is the meaning of transformer polarity? Explain and draw how to determine it in the lab? And why it is important in parallel operation of single-phase transformers?

Answer:

Polarity of transformer indicates how the windings are wound on the core. The terminal in the primary has the same polarity with one terminal in the secondary when the current inter to the terminal of primary, it will flow out to the load from the similar polarity point in the secondary in same time. Also, the polarity of the transformer can be defined as the voltage between the polarity to non-polarity are the same in both sides of the transformer. The polarity can be determined in the lab as shown in the following figure. The supply voltage will be connected to the primary and one terminal from primary is connected with one point in the secondary and voltmeter between the other two points is connected. If the voltage VPS=VP-VS this means that the voltmeter is connected between two similar polarity points. If the voltage VPS=VP+VS, the voltmeter is connected between different polarity points.

The polarity is very important when connected two single-phase transformers in parallel because if the same polarity points in the primary and secondary are not connected in right way, the circulating current will flow in the transformer winding which can destroy the two transformers.



Polarity determination in the lab. V_p, V_s, and V_{ps} are the primary, secondary, and difference between primary and secondary voltages, respectively.

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