Sana'a University
Faculty of Engineering
Department: Electrical Engineering
Title of the Program: Electrical Power and Machines Engineering

52. Course Specification of Substations Design

I. Course Identification and General Information:

1.	Course Title:	Substations Design				
2.	Course Code & Number:	PME428				
3.	Credit hours:	C.H				Total
		Th.	Tu.	Pr.	Tr.	
		2	2	-	-	3
4.	Study level/ semester at which this course is offered:	Fifth Year- First Semester				
5.	Pre –requisite (if any):	Power System Analysis 1 (PME332)				
6.	Co –requisite (if any):	None				
7.	Program (s) in which the course is offered:	BSc. Electrical Power and Machines Engineering				
8.	Language of teaching the course:	English				
9.	Location of teaching the course:	Electrical Engineering Department/Faculty of Engineering				
10.	Prepared By:	Prof. Dr. Eng. Omar H. Al-Sakaf				
11.	Date of Approval					

II. Course Description:

This course introduces students to the function of high voltage substations at all levels of the power grid, with an introduction to typical substation components included. It familiarizes students with the position and function of substations in power systems, high voltages and currents, elements of high voltage substations, especially switchgear, their basic characteristics, choice method and necessary calculations, basic and auxiliary schemes, grounding and electric accident prevention, substation reliability, measuring, control and signalization, as well as influences of substations on the environment. Students learn features, drawbacks and application of the different designs of high voltage substations and their realization as outdoor, indoor and gas-insulated substations.

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	III. Course Intended learning outcomes (CILOs) of the course	Referenced PILOs
a1	Describe the methodologies and principles of design, techniques and operation of high voltage switchgear in high voltage substations.	A1, A2, A3, A4
a2	Describe the classifications of high voltage substations layouts, their characteristics and features.	A1, A2, A3, A4
b1	Analyze engineering decisions considering balanced costs, benefits, safety, quality, reliability, and environmental impact.	B1, B2, B3, B4
b2	Identify and formulate engineering issues to solve problems in the field of high voltage substations.	B1, B2, B3, B4
c1	Apply modern techniques, skills and engineering tools to high voltage substation equipment design and selection.	C1, C2, C3, C4
c2	Develop technical specifications including testing and evaluation of components and equipment related to high voltage substations.	C1, C2, C3, C4
d1	Create systematic and methodic approaches when dealing with new and advancing technology.	D2, D3, D5
d2	Acquire problem solving and design skills and use computer applications and internet to extract information related to field of study and to prepare and present design reports.	D2, D3, D5

(A) Alignment Course Intended Learning Outcomes of Knowledge and Understanding to Teaching Strategies and Assessment Strategies:			
Course Intended Learning Outcomes		Teaching strategies	Assessment Strategies
a1	Describe the methodologies and principles of design, techniques	▪ Lectures,	▪ Assignments,

and operation of high voltage switchgear in high voltage substations.	▪ Demonstrations, ▪ Interactive class discussion, ▪ Tutorials	▪ Oral Presentations, ▪ Quizzes, ▪ Tests, ▪ Written Exams
a2 Describe the classifications of high voltage substations layouts, their characteristics and features.		

(B) Alignment Course Intended Learning Outcomes of Intellectual Skills to Teaching Strategies and Assessment Strategies:		
Course Intended Learning Outcomes	Teaching strategies	Assessment Strategies
b1 Analyze engineering decisions considering balanced costs, benefits, safety, quality, reliability, and environmental impact.	▪ Lectures, ▪ Demonstrations, ▪ Interactive class discussion	▪ Assignments, ▪ Oral Presentations, ▪ Quizzes, ▪ Tests, ▪ Exams
b2 Identify and formulate engineering issues to solve problems in the field of high voltage substations.		

(C) Alignment Course Intended Learning Outcomes of Professional and Practical Skills to Teaching Strategies and Assessment Strategies:		
Course Intended Learning Outcomes	Teaching strategies	Assessment Strategies
c1 Apply modern techniques, skills and engineering tools to high voltage substation equipment design and selection.	▪ Lectures, ▪ Demonstrations, ▪ Interactive class discussion.	▪ Assignments, ▪ Oral Presentations, ▪ Quizzes, ▪ Tests, ▪ Written Exams.
c2 Develop technical specifications including testing and evaluation of components and equipment related to high voltage substations.		

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(D) Alignment Course Intended Learning Outcomes of Transferable Skills to Teaching Strategies and Assessment Strategies:		
Course Intended Learning Outcomes	Teaching strategies	Assessment Strategies
d1 Create systematic and methodic approaches when dealing with new and advancing technology.	▪ Demonstrations, ▪ Interactive class discussion.	▪ Assignments, ▪ Oral Presentations.
d2 Acquire problem solving and design skills and use computer applications and internet to extract information related to field of study and to prepare and present design reports.		

IV. Course Content:

A – Theoretical Aspects:

Order	Units/Topics List	Learning Outcomes	Sub Topics List	Number of Weeks	Contact Hours
1.	General Introduction	a1, a2, b1, b2, c1, c2, d1, d2	▪ Classification of Substations ▪ Substation Siting ▪ Substation Design Considerations	1	2
2.	Switchgear	a1, a2, b1, b2, c1, c2, d1, d2	▪ Switching - Basic Principles ▪ The Process of Current Interruption ▪ Technical Realization ▪ Low Voltage Switchgear ▪ High Voltage Switchgear ▪ High Voltage Circuit Breakers ▪ Arc Quenching Media ▪ Sulphur Hexafluoride ▪ Vacuum	4	8

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			▪ Oil ▪ Air ▪ Selection of Circuit Breakers ▪ Switches and Disconnectors ▪ Operating Mechanisms		
3.	Substations Alternative Layouts	a1, a2, b1, b2, c1, c2, d1, d2	▪ Substations with Busbars ▪ Single Busbar Arrangement ▪ Double Busbar Arrangement ▪ Substations without Busbars ▪ Simplified High Voltage Substations Layouts	4	8
4.	Conventional Designs of Outdoor Air-Insulated High Voltage Substations	a1, a2, b1, b2,c1, c2, d1,d2	▪ Safety Clearances ▪ Conventional Designs ▪ Parallel-Transverse Layout ▪ Series-Longitudinal Layout ▪ Series-Transverse Design ▪ Diagonal Design ▪ 1½ - Breaker Layout	1	2
5.	Gas Insulated Switchgear for Substations	a1, a2, b1, b2,c1, c2, d1,d2	▪ Advantages of GIS ▪ GIS Construction ▪ Technical Realization ▪ Hybrid Substations ▪ Containerized GIS Substations ▪ Service Life and GIS Advancements	2	
6.	Substation Auxiliary Power Supplies and	a1, a2, b1, b2,c1, c2, d1,d2	▪ Substation Auxiliary Power Supplies ▪ Substation Building Services • Substation Fire Safety	1	2

	Building Services				
7.	Substation Automation Basics	a1, a2, b1, b2, c1, c2, d1,d2	▪ Substation Automation Systems ▪ Instrument Transformers ▪ Substation Control ▪ Supervisory Control and Data Acquisition SCADA System	1	2
Number of Weeks /and Units Per Semester				**14**	**28**

B – Tutorial:

Order	Tasks	Number of Weeks	Contact Hours	Learning Outcomes
1.	Analysis of high voltage substations design considerations.	**2**	4	b1, b2, c1, c2, d1, d2
2.	Problems to determine the best substation site; closest to the load center.	**1**	2	b1, b2, c1, c2, d1, d2
3.	Illustrating via flowcharting steps involved in establishing a new substation.	**1**	2	b1, b2, c1, c2, d1, d2
4.	Selecting and specifying substation main components and equipment.	**2**	4	b1, b2, c1, c2, d1, d2
5.	Reading and analyzing substation drawings and diagrams.	**1**	2	b1, b2, c1, c2, d1, d2
6.	Analyzing, comparing and assessing different substation layouts.	**2**	4	b1, b2, c1, c2, d1, d2
7.	Role-play exercises to determine the correct switching sequence.	**2**	4	b1, b2, c1, c2, d1, d2
8.	What-If scenarios to determine number of circuits lost due to faults on different substation main components and incoming/outgoing feeders.	3	6	b1, b2, c1, c2, d1, d2
Number of Weeks and Units Per Semester		**14**	**28**	

V. Teaching Strategies of the Course:

- Lectures
- Interactive class discussion
- Demonstration – Technical Video Clips
- Field Visits

VI. Schedule of Assessment Tasks for Students During the Semester:

No.	Assessment Method	Week Due	Mark	Proportion of Final Assessment	Aligned Course Learning Outcomes
1.	Mini Projects	1-14	20	20%	b1, b2, c1, c2, d1, d2
2.	Mid-Term Exam	8	20	20%	
3.	Final Exam	16	60	60%	
Total			**100**	**100%**	

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VII. Learning Resources:

1- Required Textbook(s)

- Omar Al-Sakaf, 'Introduction to High Voltage Substations Design', Second Edition, 2019, Sana'a, Yemen.

2- Essential References.

- Colin Bayliss and Brian Hardy, 'Transmission and Distribution Electrical Engineering', Third edition 2007.
- Electric Power Substation Engineering, John McDonald, ed. Boca Raton, FL: CRC Press, 2nd Edition, 2007.
- Design Guide for Rural Substations, United States Department of Agriculture, 2001, www.usda.gov/rus/electric.
- Siemens Power Engineering Guide, 6th Edition, www.ev.siemens.de, www.energy.siemens.com.
- ABB Switchgear Handbook, 11th Edition, www.abb.com.

3- Electronic Materials and Web Sites *etc*.

- Course Power Point.
- Video clips.
- Links to information resources.

VIII. Course Policies:

1.	**Class Attendance:** A student should attend not less than 75 % of total hours of the subject; otherwise he will not be able to take the exam and will be considered as exam failure. If the student is absent due to illness, he/she should bring an approved statement from university Clinic
2.	**Tardy:** For late in attending the class, the student will be initially notified. If he repeated lateness in attending class he will be considered as absent.
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4.	**Assignments & Projects:** The assignment is given to the students after each chapter; the student has to submit all the assignments for checking on time-

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5.	**Cheating:** For cheating in exam, a student will be considered as failure. In case the cheating is repeated three times during his/her study the student will be disengaged from the Faculty-
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7.	**Other policies:** - Mobile phones are not allowed to use during a class lecture. It must be closed, otherwise the student will be asked to leave the lecture room - Mobile phones are not allowed in class during the examination. Lecture notes and assignments my given directly to students using soft or hard copy

Reviewed By	**Vice Dean for Academic Affairs and Post Graduate Studies: Asst. Prof. Dr. Tarek A. Barakat** **President of Quality Assurance Unit: Assoc. Prof. Dr. Mohammed Algorafi** **Name of Reviewer from the Department: Asst. Prof. Dr. Adel Ahmed Al-Shakiri**
	Deputy Rector for Academic Affairs Asst. Prof. Dr. Ibrahim AlMutaa **Assoc. Prof. Dr. Ahmed Mujahed** **Asst. Prof. Dr. Munasar Alsubri**

Head of Department Asst. Prof. Dr. Adel Ahmed Al-Shakiri	Quality Assurance Unit Assoc. Prof. Dr. Mohammad Algorafi	Dean of the Faculty Prof. Dr. Mohammed AL-Bukhaiti	Academic Development Center & Quality Assurance Assoc. Prof. Dr. Huda Al-Emad	Rector of Sana'a University Prof. Dr. Al-Qassim Mohammed Abbas

52. Course Plan of Substations Design

I. Information about Faculty Member Responsible for the Course:

Name of Faculty Member	Prof. Dr. Eng. Omar H. Al-Sakaf	**Office Hours**					
Location& Telephone No.	Faculty of Engineering Mobile: 733772328/773332328	SAT	SUN	MON	TUE	WED	THU
E-mail	oalsakaf@gmail.com oalsakaf@yahoo.com		08:00 - 12:00				

II. Course Identification and General Information:

1.	Course Title:	Substations Design				
2.	Course Number & Code:	PME428				
3.	Credit hours:	C.H				Total
		Th.	Tu.	Pr.	Tr.	
		2	2	-	-	3
4.	Study level/year at which this course is offered:	Fifth year- First Semester				
5.	Pre –requisite:	Power System Analysis 1 (PME332)				
6.	Co –requisite (if any):	None				
7.	Program (s) in which the course is offered	BSc. Electrical Power and Machines Engineering				
8.	Language of teaching the course:	English				
9.	System of Study:	Regular				
10.	Mode of delivery:	Face-to-Face				
11.	Location of teaching the course:	Electrical Engineering Department/Faculty of Engineering				

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IV. Intended Learning Outcomes (ILOs) of the Course:

1. Describe the methodologies and principles of design, techniques and operation of high voltage switchgear in high voltage substations.
2. Describe the classifications of high voltage substations layouts, their characteristics and features.
3. Analyze engineering decisions considering balanced costs, benefits, safety, quality, reliability, and environmental impact.
4. Identify and formulate engineering issues to solve problems in the field of high voltage substations.
5. Apply modern techniques, skills and engineering tools to high voltage substation equipment design and selection.
6. Develop technical specifications including testing and evaluation of components and equipment related to high voltage substations.
7. Create systematic and methodic approaches when dealing with new and advancing technology.

   Acquire problem solving and design skills and use computer applications and internet to extract information related to field of study and to prepare and present design reports.

V. Course Content:

A – Theoretical Aspects:

Order	Units/Topics List	Sub Topics List	Number of Weeks	Contact Hours
1.	General Introduction	▪ Classification of Substations ▪ Substation Siting ▪ Substation Design Considerations	1st	2
2.	Switchgear	▪ Switching - Basic Principles ▪ The Process of Current Interruption ▪ Technical Realization ▪ Low Voltage Switchgear ▪ High Voltage Switchgear ▪ High Voltage Circuit Breakers ▪ Arc Quenching Media ▪ Sulphur Hexafluoride ▪ Vacuum ▪ Oil ▪ Air ▪ Selection of Circuit Breakers ▪ Switches and Disconnectors ▪ Operating Mechanisms	2nd ,3rd ,4th ,5th	8
3.	Substations Alternative Layouts	▪ Substations with Busbars ▪ Single Busbar Arrangement ▪ Double Busbar Arrangement ▪ Substations without Busbars ▪ Simplified High Voltage Substations Layouts	6th ,7th	4
4.	Midterm Exam		8th	2
5.	Substations Alternative Layouts	▪ Substations with Busbars ▪ Single Busbar Arrangement ▪ Double Busbar Arrangement ▪ Substations without Busbars	9th ,10th	4

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		▪ Simplified High Voltage Substations Layouts		
6.	Conventional Designs of Outdoor Air-Insulated High Voltage Substations	▪ Safety Clearances ▪ Conventional Designs ▪ Parallel-Transverse Layout ▪ Series-Longitudinal Layout ▪ Series-Transverse Design ▪ Diagonal Design ▪ 1½ - Breaker Layout	11th	2
7.	Gas Insulated Switchgear for Substations	▪ Advantages of GIS ▪ GIS Construction ▪ Technical Realization ▪ Hybrid Substations ▪ Containerized GIS Substations ▪ Service Life and GIS Advancements	12th ,13th	4
8.	Substation Auxiliary Power Supplies and Building Services	▪ Substation Auxiliary Power Supplies ▪ Substation Building Services • Substation Fire Safety	14th	2
9.	Substation Automation Basics	▪ Substation Automation Systems ▪ Instrument Transformers ▪ Substation Control ▪ Supervisory Control and Data Acquisition SCADA System	15th	2
10.	Final Exam		16th	2
Number of Weeks /and Units Per Semester			**16**	**32**

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B – Tutorial:			
Order	**Tasks**	**Number of Weeks**	**Contact Hours**
1.	Analysis of high voltage substations design considerations.	1st ,2nd	4
2.	Problems to determine the best substation site; closest to the load center.	3rd	2
3.	Illustrating via flowcharting steps involved in establishing a new substation.	4th	2
4.	Selecting and specifying substation main components and equipment.	5th ,6th	4
5.	Reading and analyzing substation drawings and diagrams.	7th	2
6.	Analyzing, comparing and assessing different substation layouts.	8th ,9th	4
7.	Role-play exercises to determine the correct switching sequence.	10th ,11th	4
8.	What-If scenarios to determine number of circuits lost due to faults on different substation main components and incoming/outgoing feeders.	12th ,13th ,14th	6
Number of Weeks and Units Per Semester		**14**	**28**

VI. Teaching Strategies of the Course:

- Lectures
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- Field Visits

VII. Schedule of Assessment Tasks for Students During the Semester:

No.	Assessment Method	Week Due	Mark	Proportion of Final Assessment	Aligned Course

					Learning Outcomes
1.	Mini Projects	1-14	20	20%	b1, b2, c1, c2, d1, d2
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