6- Course Specification of: Energy Storage Systems
Course Code (PME5315)

• General Information About the Course:

1.	**Course Title:**	**Energy Storage Systems**			
2.	**Course Code and Number:**	**PME5315**			
3.	**Credit Hours:**	**Credit Hours**			**Total**
		Lecture	Practical	Seminar/Tutorial	
		3	-	-	**3**
4.	**Study Level and Semester:**	**2nd Semester**			
5.	**Pre-requisites (if any):**	**NA**			
6.	**Co-requisites (if any):**	**NA**			
7.	**Program (s) in which the course is offered:**	MSc. In Electrical Power and Machines Engineering Program			
8.	**Language of teaching the course:**	English			
9.	**Study System:**	Courses & Thesis			
10.	**Prepared By:**	Dr. Adel Ahmed Al-Shakiri			
11.	**Reviewed by:**	Prof. Dr. Omar Hassan Al-Sakaf			
12.	**Date of Approval:**				

• Course Description:

The course "Energy Storage Systems" covers a wide area of technological content in a compact arrangement and provides a summary of the proven solutions as well as the challenges for further improvements and the necessity for innovations in energy storage methods and systems. The overview includes fundamental understanding of the operating principles, design specifications, material development and production techniques, auxiliary systems, etc. The focus is on the integration of energy storage with mainstream power generation in future electrical grids, including synergy effects in hybrid and polygeneration solutions by integrating several energy storage technologies together with several power generation sources.

• Course Intended Learning Outcomes (CILOs):

Upon successful completion of **Energy Storage Systems Course**, the graduates will be able to:

a1 - Understand Concept and operation of available and relevant energy storage systems.

a2 - Identify available technologies and materials for energy storage and their typical application areas together with their advantages and development challenges

a3 - Recognize Different needs within energy storage, cause and propagation of efficiency losses in various energy storage systems

b1 - Explain the concept and operation of available and relevant energy storage systems.

b2- Evaluate some promising aspects regarding system integration of energy storage solutions with conventional and renewable energy conversion systems and hybrid power plants;

b3- Design energy and power needs of simple hybrid systems based on output and energy capacity

c1- Calculate the efficiency of charging cycles for different energy storage systems.

c2- Assess the need for introducing energy storage within a closed energy system;

c3 - Estimate via simplified pathways the necessary dimensions, power capacity and operational parameters for energy storage systems;

d1- Communicate effectively within teams to accomplish a common goal.

d2- Engage in independent lifelong learning.

• Alignment of Course Intended Learning Outcomes (CILOs) to Program Intended Learning Outcomes (PILOs)

CILOs		PILOs
a. Knowledge and Understanding: Upon successful completion of **the Energy Storage Systems Course**, the graduates will be able to:		**A. Knowledge and Understanding:** Upon successful completion of the **MSc. In Electrical Power and Machines Engineering Program**, the graduates will be able to:
a1.	Understand Concept and operation of available and relevant energy storage systems.	**A1.** Demonstrate in-depth understanding of the theory and practice of modern electrical power systems design and operation and system identification.
a2.	Identify available technologies and materials for energy storage and their typical application areas together with their advantages and development challenges	**A2.** Recognize and comprehend the key role of sustainable energy for national and global sustainable development.
a3.	Recognize Different needs within energy storage, cause and propagation of efficiency losses in various energy storage systems	**A3.** Explain in detail the key considerations and challenges of sustainable design and development of modern electrical power system components.
b. Cognitive/ Intellectual Skills: Upon successful completion of the **Energy Storage Systems Course,** the graduates will be able to:		**B. Cognitive/ Intellectual Skills:** Upon successful completion of the **MSc. In Electrical Power and Machines Engineering Program,** the graduates will be able to:

b1.	Explain the concept and operation of available and relevant energy storage systems.	**B1.** Identify and apply specialized knowledge and skills to solve problems that are critical to future growth of industry and business.
b2.	Evaluate some promising aspects regarding system integration of energy storage solutions with conventional and renewable energy conversion systems and hybrid power plants;	**B2.** Critically review the scientific literature for effective justification and support of results and decisions.
b3.	Design energy and power needs of simple hybrid systems based on output and energy capacity	**B3.** Select appropriate techniques and tools for successful problem solving .
c. Professional and Practical Skills: Upon successful completion of the **Energy Storage Systems Course,** the graduates will be able to:		**C. Professional and Practical Skills:** Upon successful completion of the **MSc. In Electrical Power and Machines Engineering Program,** the graduates will be able to:
c1.	Calculate the efficiency of charging cycles for different energy storage systems.	**C1.** Apply modern tools for research, computation, simulation, analysis, and design of modern power systems. .
c2.	Assess the need for introducing energy storage within a closed energy system;	**C2.** Recognize the interdisciplinary nature of technical problems and apply other areas of knowledge to the solution, and work with other professions to arrive at a solution for complex engineering problems.
c3.	Estimate via simplified pathways the necessary dimensions, power capacity and operational parameters for energy storage systems;	C3 Employ design standards and safety codes as an integral part of the design and building process for machine parts and systems.
d. Transferable Skills: Upon successful completion of the **Energy Storage Systems Course,** the graduates will be able to:		**D. Transferable Skills:** Upon successful completion of the **MSc. In Electrical Power and Machines Engineering Program,** the graduates will be able to:
d1.	Communicate effectively within teams to accomplish a common goal.	**D1.** Demonstrate leadership skills in the workplace, to function professionally in a globally competitive world, and to communicate engineering results effectively. .
d2.	Engage in independent lifelong learning.	**D3.** Pursue advanced graduate studies and lifelong learning. .

• Alignment of CILOs to Teaching and Assessment Strategies

a. Alignment of Knowledge and Understanding CILOs:

Knowledge and Understanding CILOs	Teaching Strategies	Assessment Strategies

a1.	Understand Concept and operation of available and relevant energy storage systems.	▪ Lectures, ▪ Self-Learning	▪ Written Exam,
a2.	Identify available technologies and materials for energy storage and their typical application areas together with their advantages and development challenges	▪ Lectures, ▪ Seminars, ▪ Self-Learning Problems/Studies,	▪ Written Exam, ▪ Assignments
a3.	Recognize Different needs within energy storage, cause and propagation of efficiency losses in various energy storage systems	▪ Lectures, ▪ Case study,	▪ Written Exam, ▪ Assignments

b. Alignment of Intellectual Skills CILOs:

Intellectual Skills CILOs		Teaching Strategies	Assessment Strategies
b1.	Explain the concept and operation of available and relevant energy storage systems.	▪ Lectures, ▪ Simulation Exercises, ▪ Analysis and Problem Solving,	▪ Reports, ▪ Survey, ▪ Written Exam, ▪ Assignments
b2.	Evaluate some promising aspects regarding system integration of energy storage solutions with conventional and renewable energy conversion systems and hybrid power plants;	▪ Lectures, ▪ Self-Learning, ▪ Simulation Exercises, ▪ Analysis and Problem Solving,	▪ Reports, ▪ Survey, ▪ Written Exam, ▪ Assignments
b3.	Design energy and power needs of simple hybrid systems based on output and energy capacity	▪ Lectures, ▪ Analysis and Problem Solving,	▪ Written Exam, ▪ Assignments

c. Alignment of Professional and Practical Skills CILOs:

Professional and Practical Skills CILOs		Teaching Strategies	Assessment Strategies
c1.	Calculate the efficiency of charging cycles for different energy storage systems.	▪ Lectures, ▪ Case Study, ▪ Simulation Exercises,	▪ Written Research Proposal,
c2.	Assess the need for introducing energy storage within a closed energy system;	▪ Lectures, ▪ Case Study, ▪ Simulation Exercises,	▪ Written Research Proposal
c3.	Estimate via simplified pathways the necessary dimensions, power capacity and operational parameters for energy storage systems;	▪ Lectures, ▪ Case Study, ▪ Analysis and Problem Solving,	▪ Seminar Report, ▪ Written Research Proposal,

d. Alignment of Transferable (General) Skills CILOs:

Transferable (General) Skills CILOs		Teaching Strategies	Assessment Strategies
d1.	Communicate effectively within teams to accomplish a common goal.	▪ Dissertation Defenses and Presentation, ▪ Independent Study, ▪ Presenting Researches, ▪ Publish Research Papers.	▪ Written Research Proposal ▪ Written Exam, ▪ Assignments, ▪ Survey, ▪ Written Report.

d2.	Engage in independent lifelong learning.	▪ Dissertation Defenses and Presentation, ▪ Independent Study, ▪ Presenting Researches, ▪ Publish Research Papers.	▪ Written Research Proposal ▪ Assignments, ▪ Written Report.

• Course Content

1. Theoretical Aspect

Order	Topic List / Units	Sub -Topics List	Number of Weeks	Contact Hours	Course ILOs
1	An Introduction to Modern Power Systems	**1.** The Electric Power System **2.** Energy Management Systems **3.** The Regulation of the Electricity System and the Electrical Markets **4.** Exercise: A Load-Flow Algorithm with Gauss–Seidel	**2**	**6**	a.1, a.2, a3, b.1, b.2
2	Generating Systems Based on Renewable Power	**1.** Renewable Power Systems **2.** Renewable Power Generation Technologies **3.** Grid Code Requirements	**2**	**6**	b.1, b.2, b3, c.1, c.2, d.1, d.2
3	Energy Storage Technologies	**1.** The Description of the Technology **2.** Power Conversion Systems for Electrical Storage	3	9	b.1, b.2, b3, d.1, d.2
	Mid Term Exam		1	3	All
4	Cost Models and Economic Analysis	**1.** A Cost Model for Storage Technologies **2.** An Example of an Application	1	3	a.1, b.1, b.2, c.1, c.2, c3,

5	Modeling, Control, and Simulation	**1.** Modeling of Storage Technologies: A General Approach Orientated to Simulation Objectives **2.** The Modeling and Control of the Grid-Side Converter **3.** The Modeling and Control of Storage-Side Converters and Storage Containers **4.** An Example of an Application: Discharging Storage Installations Following Various Control Rules	**2**	**6**	b.1, b.2, b3, c.1, c.2, c3, d.1, d.2
6	Short-Term Applications of Energy Storage Installations in the Power System	**1.** A Description of Short-Term Applications **2.** An Example of Fluctuation Suppression: Flywheels for Wind Power Smoothing	**2**	**6**	a.1, a.2, a3, b.1, b.2, c.1, c.2,
7	Mid- and Long-Term Applications of Energy Storage Installations in the Power System	**1.** A Description of Mid- and Long-Term Applications **2.** Example: The Sizing of Batteries for Load Following in an Isolated Power System with PV Generation.	**2**	**6**	a.1, a.2, a3, b.1, b.2, c.1, c.2,
8	**Final Term Exam**		1	3	All
Number of Weeks /and Contact Hours Per Semester			**16**	**48**	

2. Practical Aspect NA				
Order	**Practical / Tutorials topics**	**Number of Weeks**	**Contact Hours**	**Course ILOs**
1	▪			
2	▪ ▪			
Number of Weeks /and Contact Hours Per Semester				

3. Tutorial Aspect: NA				
No.	**Tutorial**	**Number of Weeks**	**Contact Hours**	**Learning Outcomes (CILOs)**
1				
2				
Number of Weeks /and Units Per Semester				

• Teaching Strategies:

- Lectures,
- Seminars,
- Self-Learning
- Case studies
- Analysis and Problem Solving
- Simulations and exercises

• Assessment Methods of the Course:

- Assignments
- Seminar Reports
- Written Exams

• Tasks and Assignments:

No	Assignments/ Tasks	Individual/ Group	Mark	Week Due	CILOs (symbols)
1	Research works	Individual	5	3. 5, 7, 9	a1, a2, b1, b2, d1, d2
2	Mini/Major Project	Group	5	11	a1, a2, b1, b2, d1, d2
3	Case studies	Group	5	6, 8	a1, a2, b1, b2, d1, d2
4	Presentations	Individual	5	2, 4, 6, 8, 10, 12	a1, a2, b1, b2, d1, d2
	Total Score		**20**	==	===

• Learning Assessment:

No.	Assessment Tasks	Week due	Mark	Proportion of Final Assessment	CILOs
1	Tasks and Assignments	3,4,5,6	20	20%	a1, a2, b1, b2, d1, d2
2	Quizzes	7,9,11,13	10	10%	a1, a2, b1, b2, c1, c2, c3
3	Midterm Exam	8	20	20%	All
5	Final Exam (Theoretical)	16	50	50%	All
Total			**100**	**100%**	**===**

• Learning Resources :

1. Required Textbook(s) :

1. **Francisco Díaz-González, Andreas Sumper, Oriol Gomis-Bellmunt, Energy Storage in Power System, John Wiley & Sons Ltd, 2016.**
2. **A.G. Ter-Gazarian, Energy Storage for Power Systems, 2nd Edittion, The Institution of Engineering and Technology, London, United Kingdom, 2011**

2. Essential References:

1. **Benoît Robyns, Bruno François, Gauthier Delille, Christophe Saudemont, Energy Storage in Electric Power Grids, ISTE Ltd and John Wiley & Sons, Inc, 2015**
2. **Ziad Melhem, Electricity transmission, distribution and storage systems, © Woodhead Publishing Limited, 2013**

3. Electronic Materials and Web Sites *etc.*

1. Course Power Point.
2. Video clips.
3. Links to information resources.

• **الضوابط والسياسات المتبعة في المقرر Course Policies**	
بعد الرجوع للوائح الجامعة يتم كتابة السياسة العامة للمقرر فيما يتعلق بالآتي:	
1	**سياسة حضور الفعاليات التعليمية Class Attendance:** **- يلتزم الطالب بحضور 75% من المحاضرات ويحرم في حال عدم الوفاء بذلك.** **- يقدم أستاذ المقرر تقريرا بحضور وغياب الطلاب للقسم ويحرم الطالب من دخول الامتحان في حال تجاوز الغياب 25% ويتم اقرار الحرمان من مجلس القسم.**
2	**الحضور المتأخر Tardy:** **- يسمح للطالب حضور المحاضرة إذا تأخر لمدة ربع ساعة لثلاث مرات في الفصل الدراسي، وإذا تأخر زيادة عن ثلاث مرات يحذر شفويا من أستاذ المقرر، وعند عدم الالتزام يمنع من دخول المحاضرة.**
3	**ضوابط الامتحان Exam Attendance/Punctuality:** **- لا يسمح للطالب دخول الامتحان النهائي إذا تأخر مقدار (20) دقيقة من بدء الامتحان** **- إذا تغيب الطالب عن الامتحان النهائي تطبق اللوائح الخاصة بنظام الامتحان في الكلية.**
4	**التعيينات والمشاريع Assignments & Projects:** **- يحدد أستاذ المقرر نوع التعيينات في بداية الفصل ويحدد مواعيد تسليمها وضوابط تنفيذ التكليفات وتسليمها.** **- إذا تأخر الطالب في تسليم التكليفات عن الموعد المحدد يحرم من درجة التكليف الذي تأخر في تسليمه.**
5	**الغش Cheating:** **- في حال ثبوت قيام الطالب بالغش في الامتحان النصفي أو النهائي تطبق عليه لائحة شؤون الطلاب.** **- في حال ثبوت قيام الطالب بالغش او النقل في التكليفات والمشاريع يحرم من الدرجة المخصصة للتكليف.**
6	**الانتحال Plagiarism:** **– في حالة وجود شخص ينتحل شخصية طالب لأداء الامتحان نيابة عنه تطبق اللائحة الخاصة بذلك**
7	**سياسات أخرى Other policies:** **- أي سياسات أخرى مثل استخدام الموبايل أو مواعيد تسليم التكليفات ..... الخ**

Course Plan (Syllabus): Energy Storage Systems

Course Code (PME5315)

I. Information about Faculty Member Responsible for the Course:							
Name	**Dr. AdelAl-Shakiri**	**Office Hours**					
Location &Telephone No.	Faculty of Engineering, 772771672	**SAT**	**SUN**	**MON**	**TUE**	**WED**	**THU**
E-mail	**ashakiri62@gmail.com**						

II. General information about the course:					
1.	**Course Title**	**Energy Storage Systems**			
2.	**Course Code and Number**	**PME5315**			
3.	**Credit Hours**	**Credit Hours**			**Total**
		Lecture	**Practical**	**Seminar/Tutorial**	
		3	**-**	**-**	**3**
4.	**Study Level and Semester**	**2nd Semester**			
5.	**Pre-requisites**	**NA**			
6.	**Co –requisite**	**NA**			
7.	**Program (s) in which the course is offered**	MSc. In Electrical Power and Machines Engineering Program			
8.	**Language of teaching the course**	English			
9.	**Location of teaching the course**	**Electrical Engineering Department**			

II. Course Description:

The course "Energy Storage Systems" covers a wide area of technological content in a compact arrangement and provides a summary of the proven solutions as well as the challenges for further improvements and the necessity for innovations in energy storage methods and systems. The overview includes fundamental understanding of the operating principles, design specifications, material development and production techniques, auxiliary systems, etc. The focus is on the integration of energy storage with mainstream power generation in future electrical grids, including synergy effects in hybrid and polygeneration solutions by integrating several energy storage technologies together with several power generation sources.

IV. Course Intended Learning Outcomes (CILOs):

Upon successful completion of **Energy Storage Systems Course**, the graduates will be able to:

a1 - Understand Concept and operation of available and relevant energy storage systems.

a2 - Identify available technologies and materials for energy storage and their typical application areas together with their advantages and development challenges

a3 - Recognize Different needs within energy storage, cause and propagation of efficiency losses in various energy storage systems

b1 - Explain the concept and operation of available and relevant energy storage systems.

b2- Evaluate some promising aspects regarding system integration of energy storage solutions with conventional and renewable energy conversion systems and hybrid power plants;

b3- Design energy and power needs of simple hybrid systems based on output and energy capacity

c1- Calculate the efficiency of charging cycles for different energy storage systems.

c2- Assess the need for introducing energy storage within a closed energy system;

c3 - Estimate via simplified pathways the necessary dimensions, power capacity and operational parameters for energy storage systems;

d1- Communicate effectively within teams to accomplish a common goal.

d2- Engage in independent lifelong learning.

Order	Topic List / Units	Sub -Topics List	Number of Weeks	Contact Hours
1	An Introduction to Modern Power Systems	5. The Electric Power System 6. Energy Management Systems 7. The Regulation of the Electricity System and the Electrical Markets 8. Exercise: A Load-Flow Algorithm with Gauss–Seidel	2	6
2	Generating Systems Based on Renewable Power	4. Renewable Power Systems 5. Renewable Power Generation Technologies 6. Grid Code Requirements	2	6
3	Energy Storage Technologies	3. The Description of the Technology 4. Power Conversion Systems for Electrical Storage	3	9
	Mid Term Exam		1	3
4	Cost Models and Economic Analysis	3. A Cost Model for Storage Technologies 4. An Example of an Application	1	3
5	Modeling, Control, and Simulation	5. Modeling of Storage Technologies: A General Approach Orientated to Simulation Objectives 6. The Modeling and Control of the Grid-Side Converter 7. The Modeling and Control of Storage-Side Converters and Storage Containers 8. An Example of an Application: Discharging Storage Installations Following Various Control Rules	2	6
6	Short-Term Applications of Energy Storage Installations in the Power System	3. A Description of Short-Term Applications 4. An Example of Fluctuation Suppression: Flywheels for Wind Power Smoothing	2	6

7	Mid- and Long-Term Applications of Energy Storage Installations in the Power System	3. A Description of Mid- and Long-Term Applications 4. Example: The Sizing of Batteries for Load Following in an Isolated Power System with PV Generation.	2	6
8	Final Term Exam		1	3
Number of Weeks /and Contact Hours Per Semester			16	48

1. Practical Aspect NA				
Order	Practical / Tutorials topics	Number of Weeks	Contact Hours	Course ILOs
1	▪			
2	▪			
Number of Weeks /and Contact Hours Per Semester				

2. Training/ Tutorials/ Exercises Aspects: NA			
Order	Tutorials/ Exercises	Week Due	Contact Hours
1	▪		
2	▪		
Number of Weeks /and Contact Hours Per Semester			

V. Teaching Strategies:

- Lectures,
- Seminars,
- Self-Learning
- Case studies
- Analysis and Problem Solving
- Simulations and exercises

VI. Assessment Methods of the Course:

- Assignments
- Seminar Reports
- Written Exams

No	Assignments/ Tasks	Individual/ Group	Mark	Week Due
1	Research works	Individual	5	3. 5, 7, 9
2	Mini/Major Project	Group	5	11
3	Case studies	Group	5	6, 8
4	Presentations	Individual	5	2, 4, 6, 8, 10, 12
	Total Score		**20**	==

No.	Assessment Tasks	Week due	Mark	Proportion of Final Assessment
1	Tasks and Assignments	3,4,5,6	20	20%
2	Quizzes	7,9,11,13	10	10%
3	Midterm Exam	8	20	20%
5	Final Exam (Theoretical)	16	50	50%
Total			**100**	**100%**

• Learning Resources :

1. Required Textbook(s) :

1. **Francisco Díaz-González, Andreas Sumper, Oriol Gomis-Bellmunt, Energy Storage in Power System, John Wiley & Sons Ltd, 2016.**
2. **A.G. Ter-Gazarian, Energy Storage for Power Systems, 2nd Edittion, The Institution of Engineering and Technology, London, United Kingdom, 2011**

2. Essential References:

1. **Benoît Robyns, Bruno François, Gauthier Delille, Christophe Saudemont, Energy Storage in Electric Power Grids, ISTE Ltd and John Wiley & Sons, Inc, 2015**
2. **Ziad Melhem, Electricity transmission, distribution and storage systems, © Woodhead Publishing Limited, 2013**

3. Electronic Materials and Web Sites *etc.*

1. Course Power Point.
2. Video clips.
3. Links to information resources.

• الضوابط والسياسات المتبعة في المقرر Course Policies	
بعد الرجوع للوائح الجامعة يتم كتابة السياسة العامة للمقرر فيما يتعلق بالآتي:	
سياسة حضور الفعاليات التعليمية Class Attendance: - يلتزم الطالب بحضور 75% من المحاضرات ويحرم في حال عدم الوفاء بذلك. - يقدم أستاذ المقرر تقريرا بحضور وغياب الطلاب للقسم ويحرم الطالب من دخول الامتحان في حال تجاوز الغياب 25% ويتم اقرار الحرمان من مجلس القسم.	1
الحضور المتأخر Tardy: - يسمح للطالب حضور المحاضرة إذا تأخر لمدة ربع ساعة لثلاث مرات في الفصل الدراسي، وإذا تأخر زيادة عن ثلاث مرات يحذر شفويا من أستاذ المقرر، وعند عدم الالتزام يمنع من دخول المحاضرة.	2
ضوابط الامتحان Exam Attendance/Punctuality: - لا يسمح للطالب دخول الامتحان النهائي إذا تأخر مقدار (20) دقيقة من بدء الامتحان - إذا تغيب الطالب عن الامتحان النهائي تطبق اللوائح الخاصة بنظام الامتحان في الكلية.	3
التعيينات والمشاريع Assignments & Projects: - يحدد أستاذ المقرر نوع التعيينات في بداية الفصل ويحدد مواعيد تسليمها وضوابط تنفيذ التكليفات وتسليمها. - إذا تأخر الطالب في تسليم التكليفات عن الموعد المحدد يحرم من درجة التكليف الذي تأخر في تسليمه.	4
الغش Cheating: - في حال ثبوت قيام الطالب بالغش في الامتحان النصفي أو النهائي تطبق عليه لائحة شؤون الطلاب. - في حال ثبوت قيام الطالب بالغش او النقل في التكليفات والمشاريع يحرم من الدرجة المخصصة للتكليف.	5
الانتحال Plagiarism: – في حالة وجود شخص ينتحل شخصية طالب لأداء الامتحان نيابة عنه تطبق اللائحة الخاصة بذلك	6
سياسات أخرى Other policies: - أي سياسات أخرى مثل استخدام الموبايل أو مواعيد تسليم التكليفات ..... الخ	7