

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET434	SMART GRID TECHNOLOGIES	PEC	2	1	0	3

Preamble: This course introduces various advancements in the area of smart grid. It also introduces distributed energy resources and micro-grid. In addition, cloud computing, cyber security and power quality issues in smart grids are also introduced.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Explain the basic concept of distributed energy resources, micro-grid and smart grid
CO 2	Choose appropriate Information and Communication Technology (ICT) in smart grid
CO 3	Select infrastructure and technologies for consumer domain of smart grid
CO 4	Select infrastructure and technologies for smart substation and distribution automation
CO 5	Formulate cloud computing infrastructure for smart grid considering cyber security
CO 6	Categorize power quality issues and appraise it in smart grid context

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	2										
CO 2	3	3	3	3	2							
CO 3	3	3	3	3	2							
CO 4	3	3	3	3								
CO 5	3	3	3	3	3							
CO 6	3	3	3	3	3							

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	10	10	20
Understand (K2)	30	30	60
Apply (K3)	10	10	20
Analyse (K4)			
Evaluate (K5)			
Create (K6)			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance	: 10 marks
Continuous Assessment Test (2 numbers)	: 25 marks
Assignment/Quiz/Course project	: 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have a maximum of 2 subdivisions and carry 14 marks.

Course Level Assessment Questions**Course Outcome 1 (CO1)**

1. Explain the drivers, functions, opportunities, barriers, challenges, technologies and standards of smart grid (K2, PO1)
2. Explain the basic concept of distributed energy resources and their grid integration. (K2, PO1, PO2)
3. Explain the basic concept of microgrid. (K1, PO1)

Course Outcome 2 (CO2)

1. Choose appropriate communication technology for smart grid. (K3, PO1, PO2, PO3, PO4, PO5)

2. Explain the communication protocols and standards in Smart grid. (K2, PO1)

Course Outcome 3 (CO3)

1. Explain the features and merits of Smart Meters, for smart grid implementation. (K2, PO1, PO2, PO3)
2. Explain the role of real time pricing in smart grid. (K3, PO1, PO2, PO3)
3. Describe the concept and role of AMR and AMI in smart grid. (K2, PO1, PO2)
4. Choose various end use devices and explain their role in Home & Building Automation. (K3, PO1, PO2, PO3, PO4, PO5)
5. Explain the various methods for energy management and role of technology for its implementation. (K3, PO1, PO2, PO3, PO4, PO5)

Course Outcome 4 (CO4)

1. Explain the concept of smart substation. (K1, PO1)
2. Describe the functionalities and applications of IED in substation and distribution automation. (K2, PO1, PO2, PO3, PO4)
3. Explain the architecture components and applications of Wide Area Monitoring Systems. (K3, PO1, PO2, PO3)
4. Explain the role of PMU in WAMS. (K2, PO1, PO2,)
5. Explain the role of various application modules in distribution automation. (K2, PO1, PO2, PO3)

Course Outcome 5 (CO5)

1. Classify cloud computing based on its deployment and services. (K2, PO1)
2. Design cloud architecture of smart grid. (K3, PO1, PO2, PO3, PO4, PO5)
3. Explain the challenges and solutions related to cyber security in smart grid. (K2, PO1, PO2, PO3, PO4, PO5)

Course Outcome 6 (CO6)

1. Explain the power quality issues in smart grid. (K2, PO1, PO2)
2. Choose technologies for the mitigation of power quality issues in the smart grid. (K3, PO1, PO2, PO3, PO4, PO5)

Model Question Paper

QP CODE:

Pages:

Reg No.: _____

Name: _____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY EIGHTH SEMESTER

B.TECH DEGREE EXAMINATION,

MONTH & YEAR

Course code: EET 434**Course Name: SMART GRID TECHNOLOGIES (E)****Max. Marks: 100****Duration: 3hrs****PART A**

(Answer all questions. Each question carries 3 marks)

1. Define smart grid concept and explain its necessity.
2. Explain the concept of resilient and self-healing grid.
3. Write a note on ZIGBEE.
4. Discuss 61850 standard and its benefits.
5. Explain how automatic meter reading can make the system smarter.
6. What is meant by real time pricing?
7. Describe substation automation.
8. Explain outage management system.
9. Explain the necessity of cyber security in smart grid
10. Write a note on power quality conditioners in smart grid.

PART B

11. (a) With the help of block diagram explain the architecture of smart grid (7)
(b) What are the challenges of smart grid technology? (7)

OR

12. (a) Explain smart grid drivers (6)
(b) What are the functions of smart grid components (8)

13. (a) Explain the various communication protocols used in smart grid. (7)
(b) Write a note on Wi-Max based communication in smart grid. (7)

OR

14. (a) Write a note on various mobile communication technologies used in smart grid. (7)
(b) Explain the role of HAN in smart grid. (7)
15. (a) Explain plug in electric vehicles (7)
(b) Explain the role of phasor measurement unit in smart grid (7)

OR

16. (a) What are the advantages of smart meters? (5)
(b) What are IEDs? What are their application in monitoring and protection (9)
17. (a) With the help of block diagram explain the main features of smart substation (10)
(b) Explain GIS (4)

OR

18. (a) Explain demand side ancillary services. (7)
(b) Write a note on smart inverters. (7)
19. (a) Describe cloud architecture of smart grid. (7)
(b) Explain the role of EMC in the smart grid. (7)

OR

20. (a) Why is cyber security of prime importance in smart grid and how can it be achieved? (7)
(b) Describe the power quality issues of grid connected renewable energy source (7)

Syllabus

Module 1 Introduction to Smart Grid: Evolution of electric grid, Definitions, Need for smart grid, Smart grid drivers, Functions of smart grid, Opportunities and barriers of smart grid, Difference between conventional grid and smart grid, Concept of resilient and self-healing grid.

Components and architecture, Inter-operability, Impacts of smart grid on system reliability, Present development and international policies in smart grid, Smart grid standards.

Module 2 Information and Communication Technology in Smart Grid: Wired and wireless communication -radio mesh, ZIGBEE, 3G, 4G and 5G. Digital PLC, DSL, Wi-Max, LAN, NAN, HAN, Wi-Fi, Bluetooth, Bluetooth Low Energy (BLE), Li-Fi. Communication Protocols in Smart grid, Introduction to IEC 61850 standard and benefits, IEC Generic Object-Oriented Substation Event - GOOSE, Substation model.

Module 3 Smart grid Technologies Part I: Introduction to smart meters, Electricity tariff, Real Time Pricing- Automatic Meter Reading (AMR) - System, Services and Functions, Components of AMR Systems, Advanced Metering Infrastructure (AMI).

Plug in Hybrid Electric Vehicles (PHEV), Vehicle to Grid (V2G), Grid to Vehicle (G2V), Smart Sensors, Smart energy efficient end use devices, Home & Building Automation.

Intelligent Electronic Devices (IED) and their application for monitoring & protection: Digital Fault Recorder (DFR), Digital Protective Relay (DPR), Circuit Breaker Monitor (CBM), Phasor Measurement Unit (PMU), Standards for PMU. Time synchronization techniques, Wide Area Monitoring System (WAMS), control and protection systems (Architecture, components of WAMS, and applications: Voltage stability assessment, frequency stability assessment, power oscillation assessment, communication needs of WAMS, remedial action scheme).

Module 4 Smart grid Technologies Part II: Smart substations, Substation automation, Feeder automation, Fault detection, Isolation, and Service Restoration (FDIR), Geographic Information System (GIS), Outage Management System (OMS).

Introduction to Smart distributed energy resources and their grid integration, Smart inverters, Concepts of microgrid, Need and application of microgrid – Energy Management- Role of technology in demand response- Demand side management, Demand side Ancillary Services, Dynamic line rating.

Module 5 Cloud computing in smart grid: Private, Public and hybrid cloud. Types of cloud computing services- Software as a Service (SaaS), Platform as a service (PaaS), Infrastructure as a service (IaaS), Data as a service (DaaS), Cloud architecture for smart grid.

Cyber Security - Cyber security challenges and solutions in smart grid, Cyber security risk assessment, Security index computation.

Power Quality Management in Smart Grid- Fundamentals, Power Quality (PQ) & Electromagnetic Compatibility (EMC) in smart grid, Power quality conditioners for smart grid. Case study of smart grid.

Text/Reference Books

1. **Stuart Borlase** “Smart Grid Infrastructure Technology and Solutions”, CRC Press; 2nd edition.
2. **James Momoh**, “Smart Grid: Fundamentals of Design and Analysis”, Wiley, 2012.
3. **S. Chowdhury**, “Microgrids and Active Distribution Networks.” Institution of Engineering and Technology, 2009.
4. **Janaka Ekanayake, Kythira Liyanage, Jianzhong Wu, Akihiko Yokohama, Nick Jenkins-** “Smart Grids Technology and Applications”, Wiley, 2012.
5. **Clark W.Gellings**, “The Smart Grid: Enabling Energy Efficiency and Demand Response”, CRC Press.
6. **Jean Claude Sabonnadière, Nouredine Hadjsaïd**, “Smart Grids”, Wiley Blackwell.
7. **James Larminie, John Lowry**, Electric Vehicle Technology Explained, Wiley, 2003.
8. **Chris Mi, M. AbulMasrur, David WenzhongGao**, “Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives”, 2011, Wiley publication.
9. **Danda B. Rawat; Chandra Bajracharya**, Cyber security for smart grid systems: Status, challenges and perspectives IEEE SoutheastCon 2015, DOI: 10.1109/SECON.2015.7132891.
10. **Pillitteri, V. and Brewer, T. (2014)**, Guidelines for Smart Grid Cybersecurity, NIST Interagency/Internal Report (NISTIR), National Institute of Standards and Technology, Gaithersburg, MD, [online], <https://doi.org/10.6028/NIST.IR.7628r1>.
11. **Barker, Preston, Price, Rudy F.**, “Cybersecurity for the Electric Smart Grid: Elements and Considerations”, Nova Science Publishers Inc, 2012.
12. **Eric D. Knapp, Raj Samani**, “Applied Cyber Security and the Smart Grid: Implementing Security Controls into the Modern Power Infrastructure”, Syngress; 1st edition (26 February 2013).
13. **Richard J. Campbell**, “The Smart Grid and Cybersecurity: Regulatory Policy and Issues”, Congressional Research Service, 2011.
14. **Dariusz Kloza, Vagelis Papakonstantinou, Sanjay Goel, Yuan Hong**, “Smart grid security”, Springer.
15. **Roger C. Dugan**, “Electrical Power Systems Quality”, McGraw-Hill Publication, 3/e.
16. **G.T.Heydt**, “Electric Power Quality”, Stars in a Circle Publications, 2/e.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	Introduction to Smart Grid:	(7)
1.1	Evolution of electric grid, definitions need for smart grid, smart grid drivers, functions of smart grid, opportunities and barriers of smart grid, difference between conventional grid and smart grid, concept of resilient and self- healing grid	3
1.2	Components and architecture, inter-operability, impacts of Smart Grid on system reliability	2
1.3	Present development and international policies in smart grid.	2

	smart grid standards.	
2	Information and Communication Technology in Smart Grid:	(8)
2.1	Wired and wireless communication -radio mesh, ZIGBEE, 3G, 4G and 5G, digital PLC, DSL, Wi-Max, LAN, NAN, HAN, Wi-Fi, bluetooth, Bluetooth Low Energy (BLE), Light-Fi, substation event - GOOSE, IEC 61850 substation model	4
2.2	Communication protocols in smart grid, introduction to IEC 61850 standard and benefits, IEC Generic Object-Oriented Substation Event - GOOSE.	2
2.3	IEC 61850 ,Substation model	2
3	Smart grid Technologies Part I	(7)
3.1	Introduction to smart meters, electricity tariff, real time pricing-Automatic Meter Reading (AMR) System, services and functions, components of AMR systems, Advanced Metering Infrastructure (AMI)	2
3.2	Plug in Hybrid Electric Vehicles (PHEV), Vehicle to Grid, Grid to Vehicle.	1
3.3	Smart sensors, smart energy efficient end use devices, home & building automation, Intelligent Electronic Devices (IED) and their application for monitoring & protection, DFRA, DPRA, CBMA	1
3.4	Phasor Measurement Unit (PMU), standard for PMU. time synchronization techniques, Wide Area Monitoring, control and protection systems - architecture, components of WAMS, and applications: voltage stability assessment, frequency stability assessment, power oscillation assessment, communication needs of WAMS, remedial action scheme.	3
4.	Smart grid Technologies Part II	(7)
4.1	Smart substations, substation automation, feeder automation, fault detection, isolation, and service restoration, Geographic Information System (GIS), Outage Management System (OMS).	2
4.2	Introduction to smart distributed energy resources and their grid integration, smart inverters.	2
4.3	Concepts of micro grid, need & application of micro grid – Energy Management-Role of technology in demand response-Demand Side Management, Demand Side Ancillary Services, Dynamic Line rating.	3
5	Cloud computing in smart grid:	(8)
5.1	Public and hybrid cloud, cloud architecture of smart grid, types of cloud computing services- IaaS, SaaS, PaaS, DaaS.	2
5.2	Cyber Security - Cyber security challenges and solutions in	2

	smart grid, cyber security risk assessment, security index computation .	
5.3	Power Quality Management in Smart Grid- Fundamentals, power quality & EMC in Smart Grid.	2
5.4	Power quality conditioners for smart grid -case study of smart grid	2

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