REF. NO. : EX/PE/PE/H/T/324C/2025

NAME OF THE EXAMINATION: **B.E. POWER ENGINEERING THIRD YEAR SECOND SEMESTER - 2025**
SUBJECT: **SMART GRID SYSTEMS (HONS.)**

TIME: 3 HOURS **FULL MARKS: 100**

CO1: Describe the concepts of smart grid system and differentiate its various components (K2)	
CO2: Explain the control, communication and data monitoring topologies of smart grid system (K5)	
CO3: Analyze and explain different socio-techno-economic aspects of smart grid systems (K4, K5)	
CO4: Investigate the integration process of various renewable energy sources and energy storage systems with smart grid (K2, K5)	

Attempt All Questions

[Q1] ***Choose the correct option(s) for any TEN (10) of the following*** ***[10@2 = 20]***

(i) The components of a power transfer system are: (1) Generator (2) Step-up power transformer (3) Primary customer (4) Step-down power transformer (5) Generating substation (6) Transmission line (7) Domestic customer (8) Distribution substation (9) Distribution transformer (10) Distribution line. The hierarchical order in which power is transferred from generation to your home is:

(a) 1-2-6-4-3-10-7 (b) 1-5-2-6-4-8-3-10-9-7
(c) 1-5-2-6-8-4-10-9-7 (d) 1-2-6-4-9-10-7

(ii) Key features of the distribution domain in smart grid are:

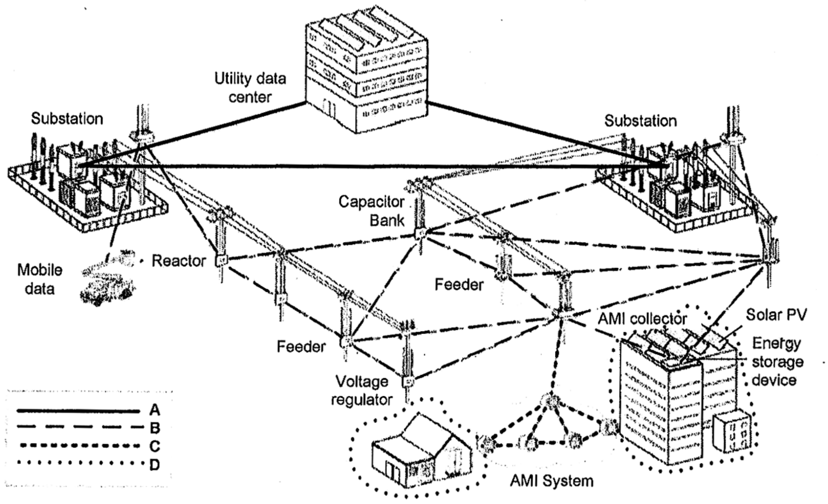
(a) Substation automation (b) Low voltage relays and circuit breakers
(c) Increasing use of DERs & their coordination (d) Distribution management system (DMS)
(e) Wide area measurement system (WAMS) (f) Communication infrastructure
(g) Distribution transformer (h) Distribution automation

(iii) Smart Grid Technology comprises of the following:

(a) AMI, AVR, LFC, Renewable Integration (b) DR/DSM, Distribution Automation, GPS
(c) MDM, WAMS, SCADA, Cyber security (d) OMS, EMS, EM Relays, Flat-rate tariff

[CO1]

(iv) Identify the communication protocols used in Outage Management System (OMS) in smart grid:



The correct order of A, B, C, D communication protocol is

(a) Core IP Network, FAN, NAN, HAN (b) WAN, NAN, FAN, HAN
(c) Core IP Network, WAN, FAN, HAN (d) Core IP Network, WAN, NAN, HAN

(v) What are the main goals of Automatic Generation Control (AGC) in smart grid?

A. keep overshoot and settling time of the governor within the acceptable ranges
B. curtail load so as to match supply with demand
C. keep the voltage and frequency of supply within specified tolerance band
D. keep the operating frequency under prescribed limits

[CO2]

[Turn over

	E. maintain the interchange power between grids through tie-lines at the intended level The correct combination is (a) A, C, D, E (b) A, D, E (c) A, B, C (d) B, C, D	
(vi)	Attributes of SCADA for Distribution Management System (DMS) in smart grid are: A. Meter reading and bill generation B. Data storage, event log, analysis and reporting C. Data acquisition D. Monitoring, event processing and alarms E. Control The correct combination is (a) A, C, D, E (b) B, C, D, E (c) A, B, D, E (d) A, B, C, D	
(vii)	The main components of Wide Area Monitoring System (WAMS) in Smart Grid are: A. Data storage B. Communication networks C. Application software D. FACTS Devices E. Phasor Data Concentrators (PDCs) F. Phasor Measurement Units (PMUs) G. Smart Energy meter H. Programmable Logic Controller (PLC) The correct combination is C, D, E, F, H (b) B, C, D, F, H (c) A, B, C, E, F (d) A, C, F, G, H	[CO3]
(viii)	Utilities make use of the following smart grid installations to improve outage management system (OMS) response: (a) AMI, FCI, DA (b) AMI, AVR, DMS (c) DA, DSM, DR (d) AVR, FCI, DMS	
(ix)	Some functions of Meter Data Management (MDM) in smart grid are: A. Direct load connect/disconnect B. Demand Control/Demand Response Support C. Reporting D. Billing Calculations E. Alarm Generation F. Smart meter firmware update G. Data Validation, Estimation, and Editing (VEE) The correct combination is (a) B, C, D, E, G (b) A, C, E, F, G (c) B, C, D, E, F (d) A, B, D, F, G	
(x)	Some of the technical challenges of Renewable Energy Source (RES) integration to power grid are: A. Interfacing B. Investment cost C. Uncontrolled variability D. Congestion management E. Cost allocation F. Voltage and frequency regulation G. Effect on power market H. Storage needs The correct choices are (a) A, B, D, G, H (b) B, C, E, F, G (c) A, C, D, F, H (d) B, D, E, G, H	
(xi)	Some of the requirements of Energy Storage System (ESS) for making it grid-compatible are: A. Reliability B. High energy density C. Water-proof D. Long life-cycle E. Cost-effectiveness F. Light-weight G. Large capacity H. Environmentally less harmful The correct choices are (a) A, B, D, E, F, H (b) A, C, D, E, G, H (c) A, C, D, F, G, H (d) A, B, D, F, G, H	[CO4]
(xii)	If you are the CEO of CESC, what up gradations you should plan in you power distribution infrastructure so that the CESC grid becomes compatible to large scale deployment of plug-in electric vehicles (PEVs) among your consumers? A. Managing the load balancing, peak hour shaving, off-peak charging, tariff structure and economic and cost-effective user billing infrastructure B. Manufacture energy efficient batteries C. Upgrade to smart grid so that PEV batteries in V2G mode can be used as distributed storage during excess RES generation hours D. Manage PEV charging facilities so that the grid is not over-burdened due to rush-hour charging E. Upgrade to smart grid so that PEV batteries G2V mode can be used as distributed generation sources during peak-load periods thereby reducing burden on conventional generating plants The correct combination is (a) A, B, C, E (b) A, C, D, E (c) A, B, C, D (d) B, C, D, E	

[Q2] Answer any ONE (1) question	*[20]*	*[CO1]*

(a) Following table compares characteristics of conventional grid with smart grid. However, the entries are jumbled up. Rearrange the entries and **correct the table**.

Characteristics	Conventional grid	Smart grid
Architecture	Centralized	Adaptive and Islanding
Asset optimization	Electromechanical only	Data driven, predictive asset management
Communication	Failures and Blackouts	Distributed
Components	Few traditional sensors (CT, PT..)	Electromechanical + Digital
Consumer Participation	Hierarchical	Extensive real time monitoring
Control	Lack of real time monitoring	Extremely quick reaction time
Disaster management	Limited control	Informed and participative
Fault response	Limited intelligence	Integrated two-way communication
Generation	Manual Check/Test	Intelligent to integrate and process critical information
Intelligence	Mostly one-way communication	Networked
Monitoring	Non-participative and uninformed	Pervasive control
Reaction time	Poor record keeping of asset	Predictive fault addressing
Self-healing	Post fault addressing	Quick and proactive response
Sensor deployment	Slow Reaction time	Remote Check/Test
Testing	Slow response	Smart net connected sensors, PMU, SCADA

(b) Different domains of smart grid and their components are listed below. Identify which components belong to which domain and **prepare a list** accordingly. [Some characteristics may be common to more than one domain]

Domains: Generation, Transmission, Distribution, Customer, Operations, Market, Service Provider

Characteristics:
Account management and controlling operations, Appropriate regulatory policies, Billing and customer complain management, Communication infrastructure, Coordinated operation of generation plants, Customers play a very important role through demand response, Development of power market, Distributed energy resources (DER), Energy-efficient transmission network, Forecasting for renewable generation, Information exchange between the distribution system operators (DSO) and the customers, Information exchange with the consumers or prosumers, Installation and commissioning services, Interact with various service providers, Introducing building or home automation system, Metering, Optimal utilization of the transmission network by system operators' pricing information availability, Real-time information exchange, Real-time monitoring and protection of the transmission network, Recording, Remote coordination of DERs by distribution system operators (DSO), Substation automation and distribution automation, Wide-area monitoring system (WAMS) enabled by communication technologies, Co-existence of various types of renewable and non-renewable generating technologies

[Q3] Answer any ONE (1) question	***[20]***	*[CO2]*

(a) (i) Fill in the blanks to derive a complete definition of Distribution Management System in Smart Grid: [4]

"Distribution Management System (DMS) is a c________ of a__________ used by the Distribution Network Operators (DNO) to m______, c______ and o______ the performance of the distribution system and is an attempt to m______ its c________"

(ii) Various functions of DMS and their acronyms are listed below. Match the acronyms with their expanded forms: [6]

Acronyms:
DNR, DSPF, DSSCC, DSSE, FISO, FLOC, RPR, SM, SRES, STPF, VVC

Expanded forms:
Distribution Network Reconfiguration, Distribution Substation Power Factor, Distribution System Power Flow, Distribution System restoration, Distribution System Short Circuit Computation, Distribution System Stability Enhancement, Distribution System State Estimation, Double Star STATCOM Control, Fault Initiation System Operation , Fault Isolation, Fault Location, Faulty Line of Contact, Relay Protection Re-coordination, Relay Protection Refurbishment, Short-Term Power Forecasting, Short-Term Prosumer Forecasting, Steady Renewable Energy System, Substation Maintenance, System Monitoring, System Restore, Volt/Var control, Voltage Variation Controller

(b) Automatic Generation Control (AGC) is essential in power system operation for ensuring frequency stability. From the following jumbled list below, **complete the Table**. [*A given type of power source can have multiple AGC components*]

Type of Power Source	Type of AGC component(s) used
Conventional rotating generators	
Solar PV systems	
Wind energy conversion systems	
Energy storage systems	
Smart grid	

Type of AGC components used:
Capacitance storage units (CES) with FACTS devices, Converters with active and reactive power support capabilities, Dynamic demand response and flexible loads, GPS for time-synchronization of PMU measurements, Intelligent and adaptive controllers such as GA/ANN/Fuzzy, Load-frequency control loops, PID controllers, Pitch angle control, PMU for tie-line power measurements, Rotor speed control, Soft computing techniques, Soft computing techniques for MPPT, Speed and frequency sensor, Virtual inertia controllers

[Q4] Answer any ONE (1) question	***[20]***	***[CO4]***

(a) Two major enabling components of Advanced Metering Infrastructure (AMI) in smart grid are Smart Meter and Meter Data Management (MDM) system. The following jumbled list contains components and functions of AMI and MDM in smart grid. **Draw a suitable flowchart** showing interrelation between these functions. Processes in the flowchart must be positioned sequentially demonstrating the data flow direction and interconnected with properly directed arrows. [*There may be multiple connections between different blocks*]

Abnormal Event Detected?	Alarm generation	Bill generation	Cyber threat	Data archiving
	Data validation	Demand response	EMS	Electric load
WAN	HAN	Load forecast	NAN	Reporting
Meter Data Management	Net metering	Tamper detection	OMS	Pre-paid metering
Meter Data Aggregator	Smart energy meter	Meter maintenance	START	STOP

(b) Match the smart grid technologies (Column A) with their definitions (Column B)

(A)Technology	(B) Definition
Smart Grid (SG)	In smart grid, it is a strategy where electricity users adjust their consumption in response to tariff rates, helping to balance supply and demand and improve grid stability
Automatic Generation Control (AGC)	It ensures the balance between electricity generation and consumption by automatically adjusting the active power output of generators to maintain frequency stability and grid reliability
Load Frequency Control (LFC)	It is a central data repository system that supports storage, archiving, retrieval & analysis of smart meter data and various other MIS along with validation & verification algorithms
Energy Management System (EMS)	It is a collection of applications used by the Distribution Network Operators (DNO) to monitor, control and optimize the performance of the distribution system and is an attempt to manage its complexity
Distribution Management System (DMS)	It is a computer system that comprises a software platform providing essential support services for smart grid, and a set of applications providing the functionalities necessary for the efficient operation of power generation, transmission and utilization facilities to ensure security of energy supply at minimum cost
Demand Side Management (DSM)	It is a software solution for smart grid that helps utilities efficiently manage power outages by integrating with various systems to detect, locate, prioritize, and restore power
Meter Data Management (MDM)	It is a system consisting of modern electronic-digital hardware and software, that can measure, collect, transfer and analyze energy usage in real time and share this information with different stakeholders as needed
Outage Management System (OMS)	It is an advanced measurement technology that consists of advanced information tools and infrastructure which facilitates operation of the complex smart grid network by collecting and processing data. It enhances grid monitoring, control, and optimization by using real-time data from Phasor Measurement Units (PMUs)
Wide Area Monitoring System (WAMS)	It is crucial for maintaining a stable and reliable electricity supply in smart grid by balancing generation and demand, ensuring a stable frequency, and enabling efficient electricity exchanges
Advanced Metering Infrastructure (AMI)	It is equipped with Automation, Communication and IT systems that can monitor power flows from generation to consumption and control the power flow or curtail the load to match generation in real time or near real time

[Q5] Answer any ONE (1) question	*[20]*	*[CO5]*

(a) Integrating renewable energy (RE) sources to smart grid can bring hosts of benefits. However, there are several challenges to be overcome for seamless integration of RE to grid. The following jumbled list contains several performance parameters that either gets (A) **enhanced** or (B) **reduced** due to RE integration to grid. Complete the following the table accordingly by putting a tick mark (√) against appropriate boxes.

Performance Parameters	**Enhanced**	**Reduced**
Availability of supply to customer	☐	☐
Cyber-physical security	☐	☐
Ease of active and reactive power control	☐	☐
Ease of maintaining system stability	☐	☐
Electricity price	☐	☐
Environmental friendliness	☐	☐
Frequency regulation	☐	☐
Harmonics	☐	☐
Investments in transmission infrastructure enhancement	☐	☐
Lead-time	☐	☐
Need for accurate forecasting	☐	☐
Need for storage systems	☐	☐
Network congestion problem	☐	☐
Protection system design complexity	☐	☐
Quality of power supply	☐	☐
Reliability of generation	☐	☐
Requirement of accurate metering	☐	☐
Response flexibility	☐	☐
Short circuit levels	☐	☐
Transmission and distribution losses	☐	☐
Utilization of local resources	☐	☐
Variability	☐	☐
Voltage and current transients	☐	☐
Voltage regulation	☐	☐
Voltage support capability	☐	☐
Voltage unbalance	☐	☐

(b) For offering benefits to grid-scale storage, energy storage systems (ESS) in smart grid should meet certain performance requirements. The following list contains the desired performance requirements of ESS to be beneficial to grid-scale storage. Identify which are (A) the benefits, and which are (B) the requirements of ESS for use in smart grid, and write them in two separate columns with proper column headings in a **Tabular form**. [*There are some dummy entries*]

Jumbled list of Benefits OR Requirements of ESS in Smart grid:
Avoiding dispatch for high tariff power plants, Balancing RES variability, Black-start services, Capacity investment deferral, communication ability, component of SCADA, congestion management, cost-effectiveness, easy scale-up potential, emergency support, environmentally benign, frequency support, grid compatibility, help in meter data management (MDM), high energy density, large capacity, long cycle life, outage management, postponement in T&D infrastructure upgradation, ramping flexibility, rapid charge/discharge rates, reduced curtailment of RE generation, increased reliability, improved safety, stable operation and performance, system balancing, tamper proofing, voltage support

----------------------------------- End of Question paper ____________________