Roll No											

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

END TERM FINAL EXAMINATION

Semester: Odd Semester: 2019 - 20

Course Code: EEE 407

Course Name: SMART GRID TECHNOLOGIES

Program & Sem: B.Tech (All Programs) & VII (OE–II)

Date: 26 December 2019

Time: 9:30 AM to 12:30 PM

Max Marks: 80

Weightage: 40%

Instructions:

(i) Read the all questions carefully and answer accordingly.

(ii) Sketch the diagrams legibly.

Part A [Memory Recall Questions]

Answer all the Questions. Each Question carries 2 marks. **(10Qx2M=20M)**

1. What makes the Grid Smart and list the primary objectives of smart grid (C.O.No.1) [Knowledge]
2. How does accommodating all generations and enabling new products, services and markets be the functionality of SG. (C.O.No.1) [Knowledge]
3. Recall the concept of AMI Technology (C.O.No.2) [Knowledge]
4. List out any four benefits and applications of IOT in SG (C.O.No.2) [Knowledge]
5. List out any four V2G Advantages and challenges (C.O.No.3) [Knowledge]
6. How can support of renewable energy sources be considered as an advantage of V2G (C.O.No.3) [Knowledge]
7. Picture the concept that creates big data analytics (C.O.No.4) [Knowledge]
8. Picture the wireless communication technology and its evolution over the years (C.O.No.4) [Knowledge]
9. Give the classification of Energy storage system (C.O.No.5) [Knowledge]
10. Recall the benefits of ESS (C.O.No.5) [Knowledge]

Part B [Thought Provoking Questions]

Answer all the Questions. Each Question carries 10 marks. **(4Qx10M=40M)**

11. (a) New threats are emerging which is very hard to eliminate the cyber security attacks, those can be mitigated in prevention and detection. Illustrate the mitigation plans. [8M]

    (b) Develop the layers and arrange the architecture in a diverse way for making the grid as smart [2M] (C.O.No.2) [Comprehension]

PRESIDENCY UNIVERSITY
BENGALURU

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

SCHOOL OF ENGINEERING

Semester: Odd Semester: 2019 - 20
Course Code: EEE ~~310~~ 407
Course Name: SMART GRID TECHNOLOGIES
Program & Sem: B.Tech (EEE) & 7th.

Date: 26th Dec 2019
Time: 9:30 AM – 12:30PM
Max Marks: 80
Weightage: 40 %

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO (% age of CO)	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels	Thought provoking type [Marks allotted] Bloom's Levels	Problem Solving type [Marks allotted]	Total Marks
			K	C	C	
PART A Q. NO 1 - 10	CO 01 CO 02 CO 03 CO 04 CO 05	All the 5 modules	[10*2 = 20M]			20
PART B Q.NO.11	CO 02	MODULE 02	-	10M		10
PART B Q.NO.12	CO 03	MODULE 3	-	10M		10
PART B Q.NO.13	CO 04	MODULE 4	-	10M		10

PART B Q.NO.14	CO 05	MODULE 5	-	10M		10
PART C Q.NO.15	CO 04	MODULE 04	-		10M	10
PARTC Q.NO.16	CO 05	MODULE 05	-		10M	10
	Total Marks		20	40	20	80

K =Knowledge Level C = Comprehension Level, A = Application Level

C.O WISE MARKS DISTRIBUTION:

CO 01: 4 MARKS, CO 02: 14 MARKS, CO 03: 14 MARKS, CO 04: 24 MARKS and CO 05: 24 MARKS

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

I hereby certify that all the questions are set as per the above guidelines.

Faculty Signature:

Reviewer Commend:

Annexure- II: Format of Answer Scheme

SCHOOL OF ENGINEERING

SOLUTION

Semester: Odd Semester: 2019 - 20

Course Code: EEE 310

Course Name: ELECTRICAL POWER GENERATION

Program & Sem: B.Tech (EEE) & 5th.

Date: 26th Dec 2019

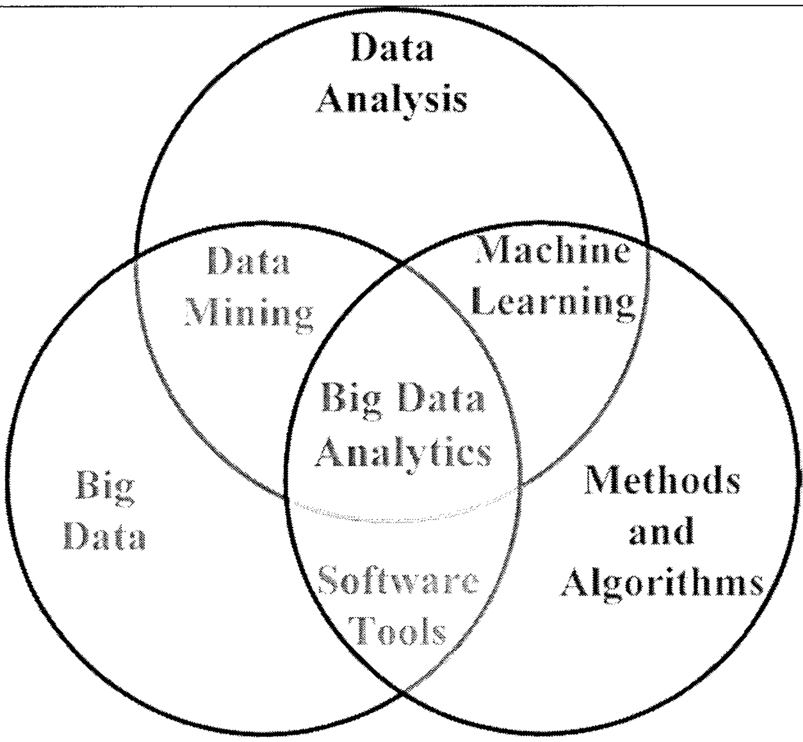
Time: 9:30 AM – 2:30PM

Max Marks: 80

Weightage: 40 %

Part A (10 x 2M = 20Marks)

Q o	Solution	Scheme of Marking	Max. Time required for each Question
1	• Managing Activities – Personal Banking – Similarly Electricity. • No Waiting for Monthly Electricity bills – Smart Meter Installation. • Check the Used electricity – when – cost with real time pricing – Saving money. • Managing Electricity – Home appliances- Purchase electricity – Self power generation **PRIMARY OBJECTIVES OF SMART GRIDS:** • National integration; • Self-healing and adaptive: improve distribution and transmission system operation; ' • Allow customers freedom to purchase power based on dynamic pricing; ' • Improved quality of power: less wastage; ' • Integration of large variety of generation options;	2M	3Min
2	• As smart grids continue to support traditional power loads they also seamlessly interconnect fuel cells, renewable, micro-turbines, and other distributed generation technologies at local and regional levels. Integration of small-scale, localized, or on-site power generation allows residential, commercial, and industrial customers to self-generate and sell excess power to the grid with minimal technical or regulatory barriers. This also improves reliability and power quality, reduces electricity costs, and offers more customer choice. • Significant increases in bulk transmission capacity will require improvements in transmission grid management. Such improvements are	2M	3Min

	• The implementation of V2G can provide frequency regulation, harmonics filtering and even failure recovery to the power system during blackout • The V2G technology can provide uninterrupted power support for home and backup energy storage for home renewable energy resources Challenges: • Battery Degradation • High Investment Cost • Social Barriers		
	Energy generation plants and transportation sector are the two major sources of carbon dioxide emission. This has reached a level that threatens the public health and environment. The deployment of renewable energy generation can help to protect the environment. However, the power generation of renewable energy sources is strongly dependent on the environmental fac- tors. The unpredictable and inconsistent energy production is the drawback of renewable energy resources. The integration of EVs in the power system can be a solution to the issues above. The intermittency issue of renewable energy resources can be solved by utilizing a fleet of EVs as energy back up so energy storages. The EV fleets act as the energy backups to supply necessary power when the renewable energy generation is in sufficient. Meanwhile, they act as energy storages to absorb the excessive power generated by renewable energy resources, which would otherwise be curtailed. Research has shown that larger renewable energy capacity can be accommodated in to the power system with more grid-connected EV battery capacity. Therefore, EV is able to improve the economics of the renewable energy generation industry. With proper energy management between renewable energy resource and EV, the future power grid will be cleaner and more sustainable	2M	3Min
7		2M	3Min

these predefined access privileges to grid devices and system functionalities reduces likelihood of malicious access to network devices. Access controls such as Discretionary Access Control (DAC), Mandatory Access Control (MAC) and Role Based Access Controls (RBAC) can increase the system reliability and eliminate potential security threats. Since IoT based SG is a cyber-physical system that is monitored and configured remotely, access controls are vital in order to limit users' and devices access in the network.

4.3.2 Encryption

When deploying IoT solutions, there is need to encrypt traffic flowing between IoT devices and the control centers including the utility provider's servers. Ensuring that the communications are encrypted using strong encryption tools is crucial as it reduces an attacker's ability to either hijack communications or generate valid data in order to fool the system. This ensures that both the integrity and confidentiality of data communications is maintained.

4.3.3 Authentication

This involves identifying devices in the network and authorizing what each device should carry out in the network. Device authentication is normally the first step of a data communication session, and its result is often a shared session key for encrypting and authenticating subsequent data packets and ensuring data integrity. Due to the time-sensitive and traffic-intensive nature of IoT smart grid communication, an authentication scheme should involve minimal exchange of messages between the grid devices. Authentication ensures meter will not accept commands from an unauthorized 3rd party. Authentication involves both identification and authorization.

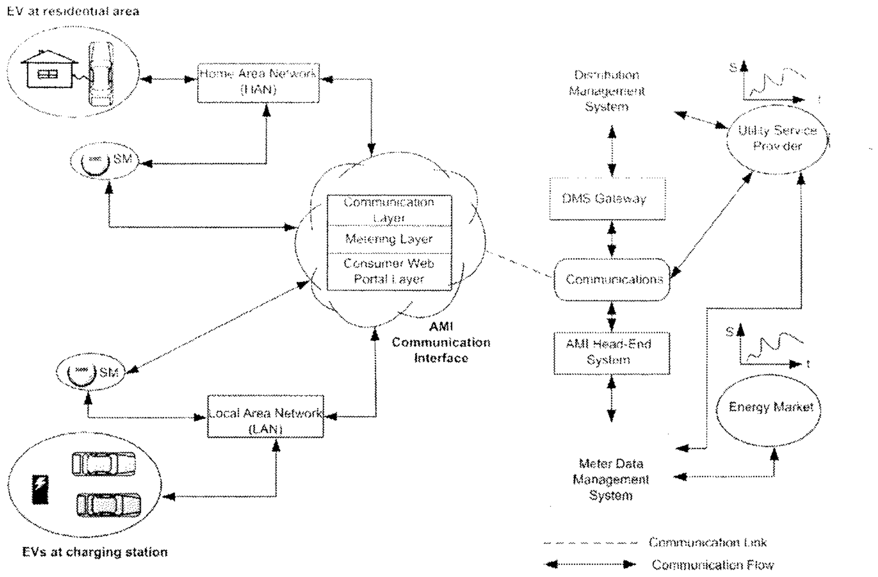
4.3.4 Regular Security Patches and Updates

IoT devices should be easily upgradable so that bugs and security updates can be deployed in an easy and manageable way. Unfortunately, most manufactures currently build devices without thinking about deploying future firmware updates at all. However, they need to appreciate that due to evolution of technology, operating systems and application code may be faced by emerging threats and vulnerabilities in future and that the rollout of updates to address these issues is paramount. Deploying firmware updates can be tricky if they're not configured to receive the updates. Considering the sheer size of an IoT smart grid, regular update to upgrade the firmware is the logical and reasonable solution as compared to a large-scale replacement of the obsolete devices. Cyber security challenges are particularly amplified when businesses integrate new and old systems without regard to overall network security. Hence, ensuring a consistent process that allows for flexible firmware deployment will allow the patching up of security loopholes across the network hence mitigating potential threats.

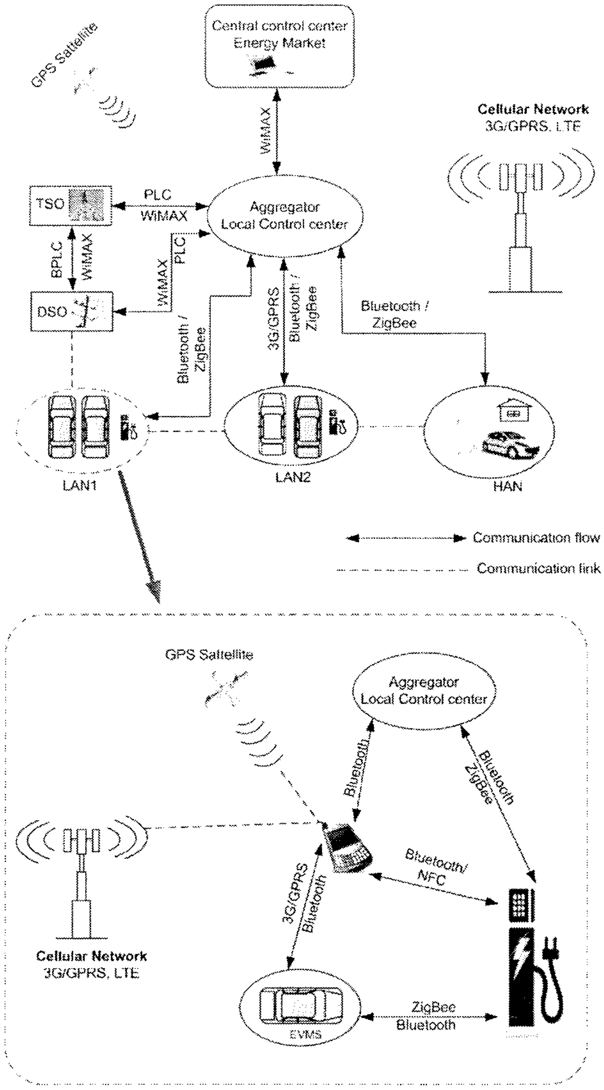
4.3.5 Physical Security

The physical security of connected grid devices is of utmost importance. Tamper-proof mechanisms should be employed and integrated into grid components to safeguard them from physical unauthorized access. The physical access by unauthorized personnel might result in data stored in the devices being compromised. Such data might include authentication, identification, usage and account information. Remote wiping capabilities should therefore be in place to erase or lock network devices to protect sensitive private data from leaking as they might be used maliciously by the intruders. Also equally important is the physical security of the premises where the servers and the control rooms are located. These provide a central location from where easy access to the whole IoT smart grid is easily available for anyone intending ill harm to the grid such as hackers and from disgruntled former or current employees. They therefore have to be secured as they pose a risk to the security of the whole network.

4.3.6 Backdoors and Logins


EV at residential area
Home Area Network (HAN)
SM
Communication Layer
Metering Layer
Consumer Web Portal Layer
AMI Communication Interface
SM
Local Area Network (LAN)
EVs at charging station
Distribution Management System
Utility Service Provider
DMS Gateway
Communications
AMI Head-End System
Energy Market
Meter Data Management System
Communication Link
Communication Flow

(b)


GPS Sattellite
Central control center
Energy Market
WiMAX
Cellular Network
3G/GPRS, LTE
TSO
PLC
WiMAX
Aggregator
Local Control center
BPLC
WiMAX
WiMAX
PLC
DSO
Bluetooth / ZigBee
3G/GPRS
Bluetooth / ZigBee
Bluetooth / ZigBee
LAN1
LAN2
HAN
Communication flow
Communication link
GPS Sattellite
Aggregator
Local Control center
Bluetooth
Bluetooth ZigBee
Bluetooth/ NFC
3G/GPRS Bluetooth
Cellular Network
3G/GPRS, LTE
ZigBee
Bluetooth
EVMS

14

(a)

Benefits	Characteristics power requirement, response time, and storage/discharge time	Energy storage technology
Peak shaving	100 kW–100 MW, seconds to minutes, and 1–10 h	Lead-acid, Li-Ion, and Vanadium Redox Flow Batteries (VRFBs), fuel cells, ZnBr, NaS, and NiCd
Energy management	< 1 MW, milliseconds to seconds, and ~2–10 h	PHS, NaS, ZnBr, VRFB, Li-Ion, and flywheel
Load levelling	More than 100 MW, minutes, and up to 10 h	Lead-acid, SMES, Li-Ion, PHS, CAES, VRFB, ZnBr, and fuel cells
Power fluctuations	Few hundred kW, milliseconds, and few seconds	Flywheel, SMES, super-capacitor, and VRFB
T&D upgrade deferral	10–100 MW, seconds, and 1–10 h	PHS, CAES, VRFB, and fuel cells
Frequency regulation	1–5 MW, milliseconds to seconds, and few minutes to 1	NaS, Lead-acid, $NaNiCl_2$, NiCd, ZnBr, and super-capacitors
Low voltage ride through	< 10 MW, ~milliseconds, and few seconds to minute	Lead-acid, $NaNiCl_2$, Li-Ion, NaS, and super-capacitors
Loss minimization	~100 MW, milliseconds, and few seconds	SMES, NaS, ZnBr, VRFB, Li-Ion, and flywheel
Reliability improvement	~1 MW, milliseconds, and few minutes to ~5 h	Super-capacitor, SMES, lead-acid, VRFB, and NaS
Reserve application	1–100 MW, few seconds, and minutes to few hours	CAES, flywheel, VRFB, ZnBr, fuel cell, NiCd, and PHS
Demand response	< 1 MW, seconds, and ~1–10 h	Li-Ion, VRFB, ZnBr, flywheel, and $NaNiCl_2$
Electric/hybrid vehicles	~50 kW, milliseconds, and minutes to hours	Li-Ion, lead-acid, super-capacitors, and fuel cells

(b)

VI. FACTORS AFFECTING SIZING OF ENERGY STORAGE

There are multiple factors which decide the size of energy storage.

A. Battery degradation

The design consideration for the optimal sizing of BESS has to undertake some key battery parameters, and battery degradation is one of them. Apart from its rated life, there are other factors which deteriorate the battery capacity.

1. Depth of discharge

Depth of discharge (DOD) represents the amount of capacity used by the battery relative to its total battery capacity. DOD is a major factor in the lifespan of the battery as it allows for deep charge/discharge cycles. Unlike sodium sulphur batteries which can bear 100% DOD, the lifetime of other battery chemistries will be severely impacted by the DOD value. The optimal DOD should be selected to increase the efficiency and longevity of the battery. The relationship between the lifecycle and DOD is normally presented in a curve which varies across different battery types. A typical curve is shown in [illegible] for the lithium ion battery at a temperature of 20°C.

2. Battery lifetime

The lifetime of the battery is the most important factor in the cost operation of BESS. The number of lifecycles a battery can sustain in its entire life depends on the charging and discharging schedule of the battery. The lifetime degradation of the battery is affected by two main factors; the lifecycle aging reflecting the number of cycles that the battery has accomplished and the decrease in battery capacity. [illegible] The lifetime equation varies with the type of battery used. However, it can be extended with a proper selection of the depth of discharge and cycle depth.

3. Temperature

The degradation of the battery life is dependent on the ambient temperature by a phenomenon called capacity fading. It analyses the reduction in the total capacity of the battery operating at a certain temperature after it experiences a particular number of charging and discharging cycles. This phenomenon has been observed at both high and low temperatures to evaluate its impact on the performance of the battery. The internal resistance of the battery increases at low temperature, whereas battery chemical reaction increases at high temperatures, which degrades the electrodes. The capacity fading percentage changes with the battery characteristics provided by the manufacturers.

4. Charge and discharge current

Another factor constituting the battery degradation is the charge and discharge currents. The high current during charging and discharging operation negatively affects the battery lifespan. The battery capacity also reduces when supplying large currents due to the increase in the internal resistance. Thus, charge and discharge power should be limited to specific values to avoid the damage of BESS.

B. Reliability

The reliability of the microgrid is essential for determining the optimal size of energy storage. The reliability criteria should satisfy the reliability indices available in terms of generation adequacy and economic factors. The energy storage provides feasible solutions for satisfying the microgrid reliability levels efficiently. Load curtailment and load leveling are viable options to achieve the reliability indices in the microgrid.

C. Battery placement

Research into the optimal placement of BESS in a microgrid is still at its infancy. To minimize the losses and improve system stability, energy storage must be allocated appropriately. The optimum location may lead to reduction in the energy purchased from the main grid, which decreases the cost of the microgrid. The optimal storage location which can support the high penetration of RES is selected by performing tests for different scenarios.

5+5=10M

15M

(b)

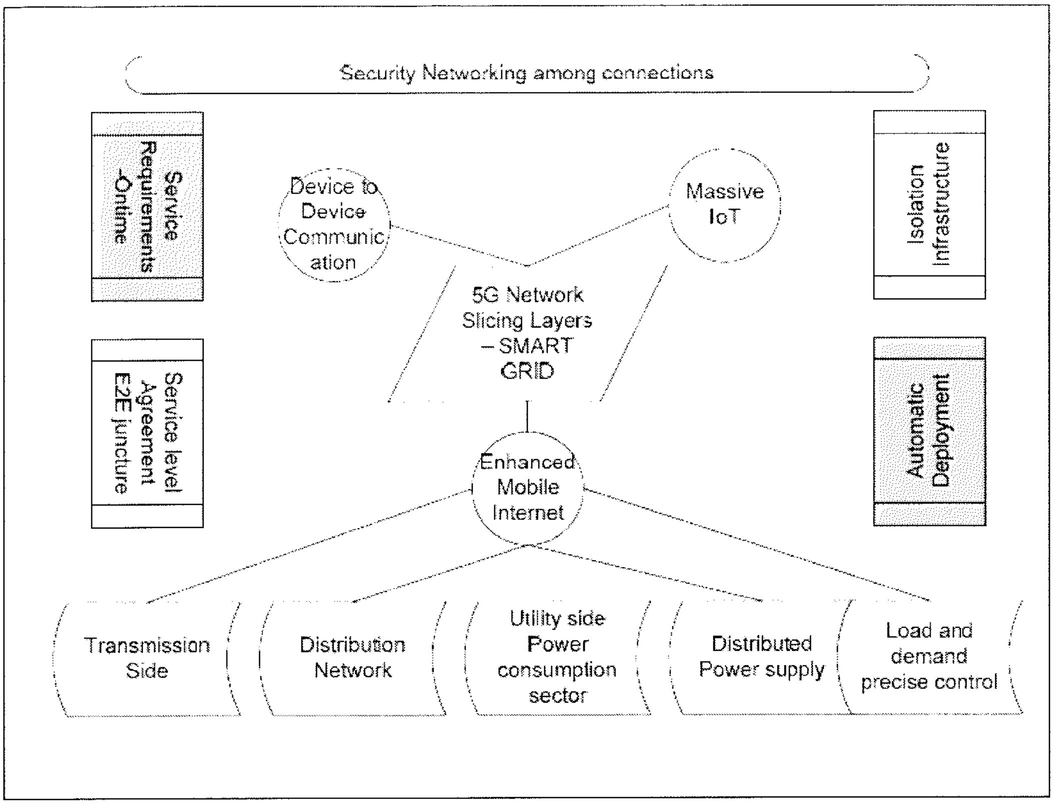


Figure 3. Roadmap architecture of 5G and smart grids.

(c)

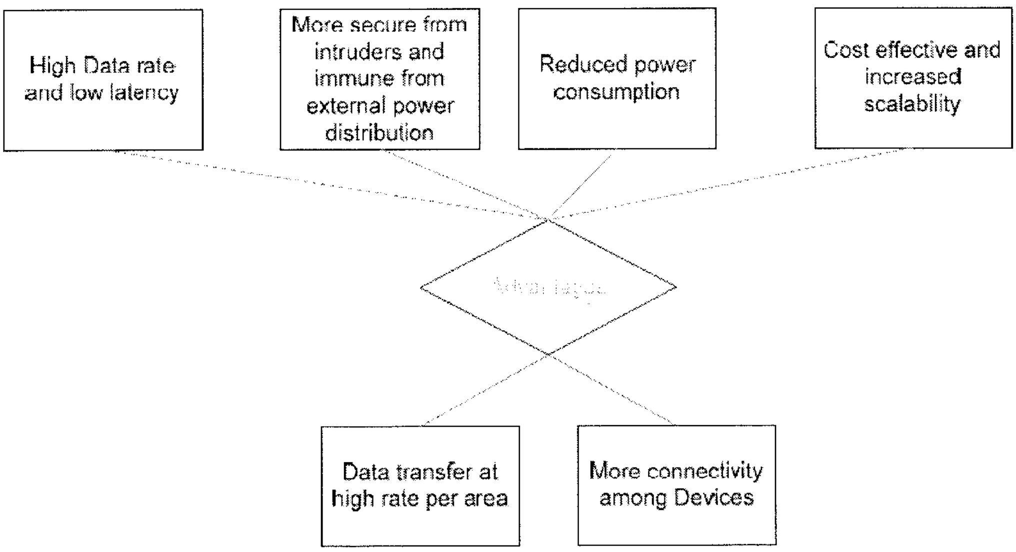


Figure 5. Benefits of 5G networks in smart grids.

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PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST – 2

Sem & AY: Odd Sem 2019-20

Course Code: EEE 407

Course Name: SMART GRID TECHNOLOGY (OE)

Program & Sem: B.Tech & VII (OE)

Date: 18.11.2019

Time: 1.00 PM to 2.00 PM

Max Marks: 40

Weightage: 20%

Instructions:

(i) Question paper consists of three parts.
(ii) Answer all the questions according to the marks.
(iii) All the diagrams are to be sketched legibly.

Part A [Memory Recall Questions]

Answer the Question. **(1Qx5M=5M)**

1. (a) Briefly ~~list out the~~ counter measures for cyber security in smart grid. **(CO2)**
[Comprehensive] [2.5M].

(b) List out the advantages and disadvantages of vehicle to grid method. **(CO3)**
[Comprehensive] [2.5M].

Part B [Thought Provoking Questions]

Answer the Question. **(1Qx15M=15M)**

2. (a) Recall the overview of AMI architecture in vehicle to grid framework. **(CO3)**
[Comprehension] [7.5 M].

(b) Explain the EV communication network architecture with smart grid **(CO3)**
[Comprehension] [7.5 M].

Part C [Problem Solving Questions]

Answer all the Questions. Each Question carries four marks. **(5Qx4M=20M)**

3. List the benefits of IOT based SG. **(CO2) [Comprehension] [4M]**
4. Briefly explain the classification of cyber-attacks. **(CO2) [Comprehensive] [4M]**
5. Explain IOT Security parameters. **(CO2) [Comprehensive] [4M]**
6. Diagrammatically explain how the real time generation monitoring from IOT based control center can happen **(CO2) [Comprehensive] [4M]**
7. Distinguish among the different types of smart meters and their growth in industry **(CO2) [Comprehensive] [4M]**

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

Annexure- II: Format of Answer Scheme

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

SOLUTION

Semester: **5th**

Course Code: EEE407

Course Name: Smart Grid Technologies

Date: -11-2019

Time: 1Hr.

Max Marks: 40M

Weightage: 20%

Part A (1 x 10M = 10Marks)

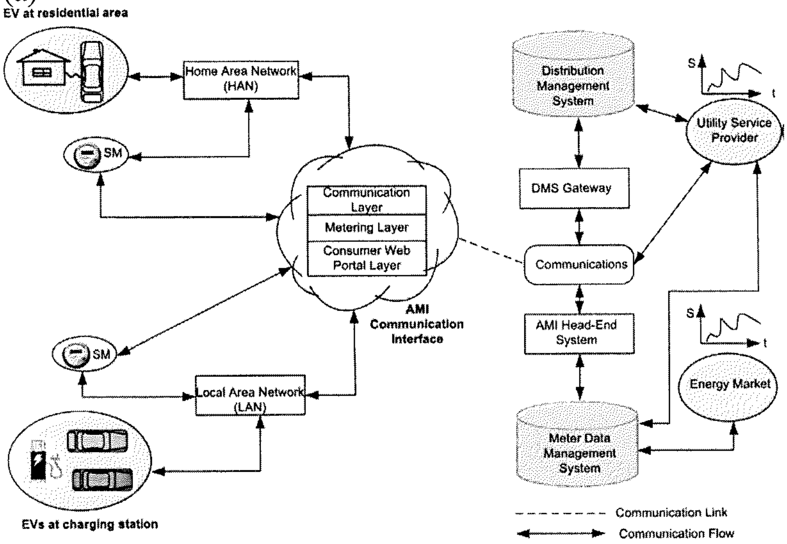
Q No	Solution	Scheme of Marking	Max. Time required for each Question
1	(a) Limiting attack Surfaces. Secrecy Integrity. Availability (b) Advantages • The implementation of V2G can provide frequency regulation, harmonics filtering and even failure recovery to the power system during blackout • The V2G technology can provide uninterrupted power support for home and backup energy storage for home renewable energy resources Disadvantages: • Battery Degradation • High Investment Cost: • Social Barriers:	(a) Countermeasures (2.5M) (b) Advantages and Disadvantages (2.5M) = 5M	5Min

Part B (3Q x 5M = 15Marks)

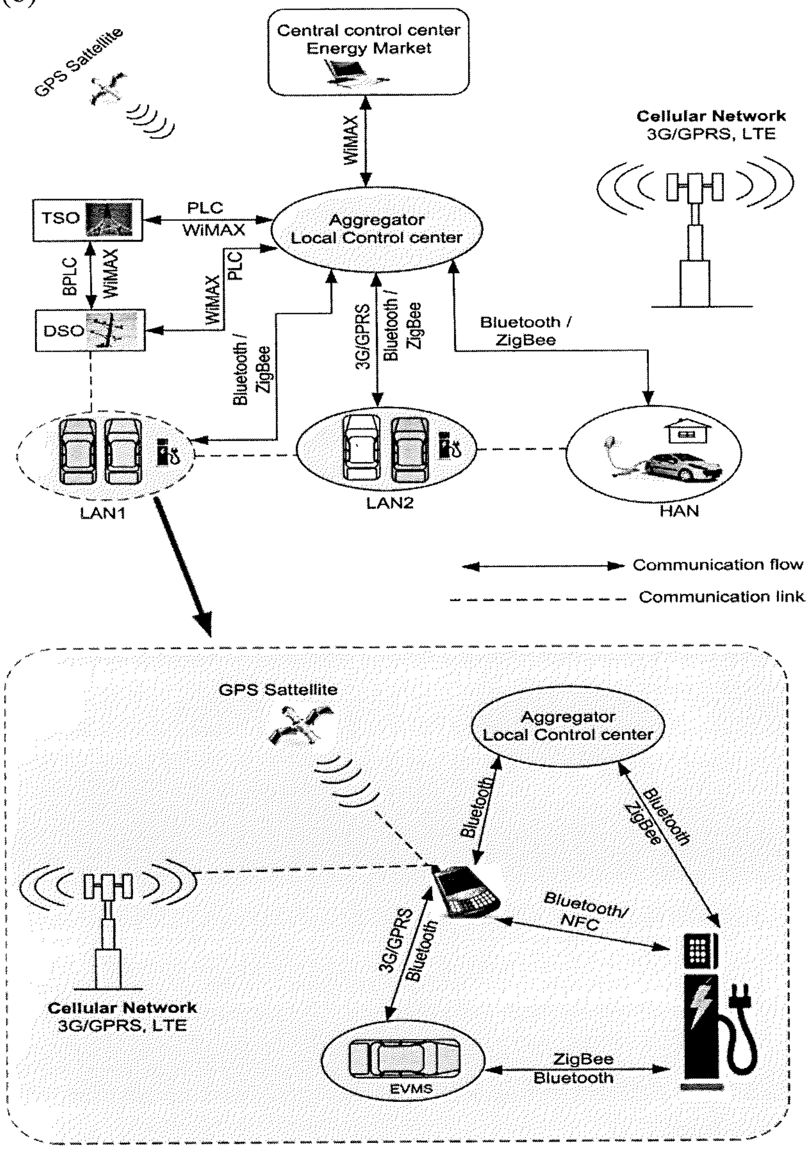
Q No	Solution	Scheme of Marking	Max. Time required for each Question

<table>
<tr><td>2</td><td>

(a)



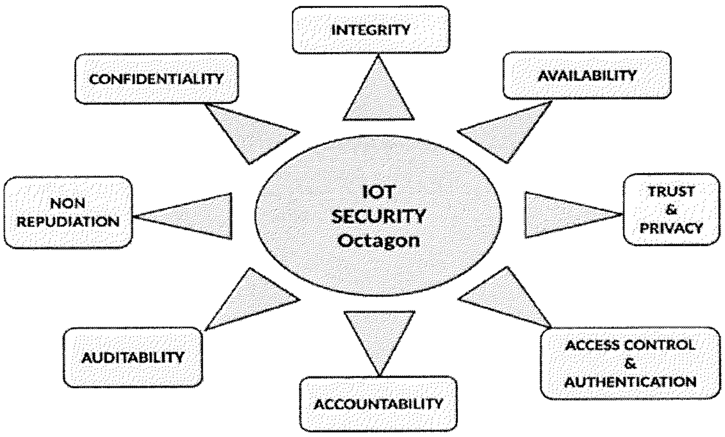
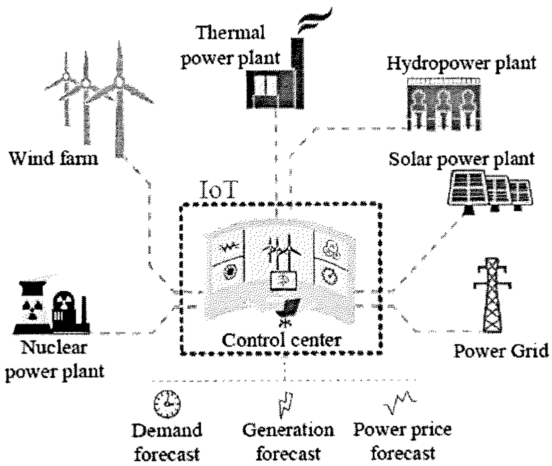
(b)

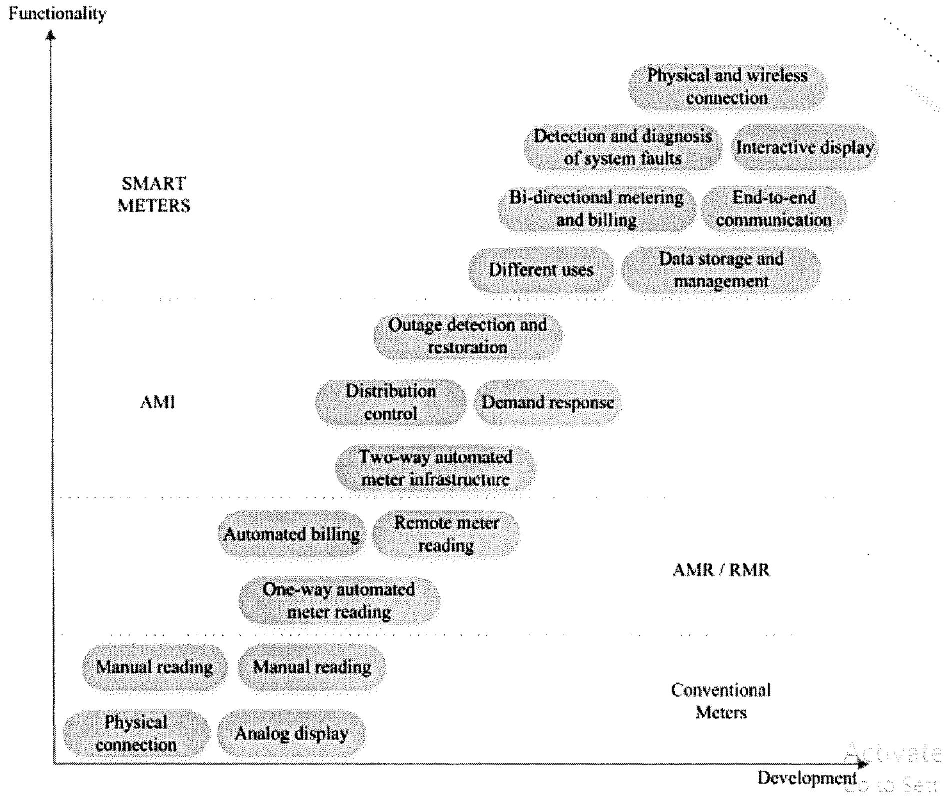


</td><td>(a) Architecture (3M)
Explanation of Framework (4.5M)
= 7.5M

(b) Diagram (4M)
Explanation (3.5M)
= 7.5M</td><td>20Min</td></tr>
</table>

Part C (any one to be answered) (1 x 10M = 10Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
3	• Advance Metering Infrastructure. • Improved reliability of the power system • Enhanced functions of SCADA (Supervisory Control and Data Acquisition) • Management of power in the grid • Demand Response • Interaction with end-customer. • Monitoring the status and operation of grid assets	(4M)	5Min
4	• Device Attack • Data Attack • Privacy Attack • Network Attack	(4M)	5Min
5		Diagram (2M) List of Parameters (2M) = 4M	5Min
6	 Figure 2. Real-time generation monitoring from an IoT-based control center	Diagram (2M) Explanation (2M) = 4M	5Min

7		Diagram 4M	5Min

Roll No											

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END TERM FINAL EXAMINATION

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Part B [Thought Provoking Questions]

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SCHOOL OF ENGINEERING

Semester: Odd Semester: 2019 - 20
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Extract of question distribution [outcome wise & level wise]

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PART B Q.NO.12	CO 03	MODULE 3	-	10M		10
PART B Q.NO.13	CO 04	MODULE 4	-	10M		10

PART B Q.NO.14	CO 05	MODULE 5	-	10M		10
PART C Q.NO.15	CO 04	MODULE 04	-		10M	10
PARTC Q.NO.16	CO 05	MODULE 05	-		10M	10
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Faculty Signature:

Reviewer Commend:

Annexure- II: Format of Answer Scheme

SCHOOL OF ENGINEERING

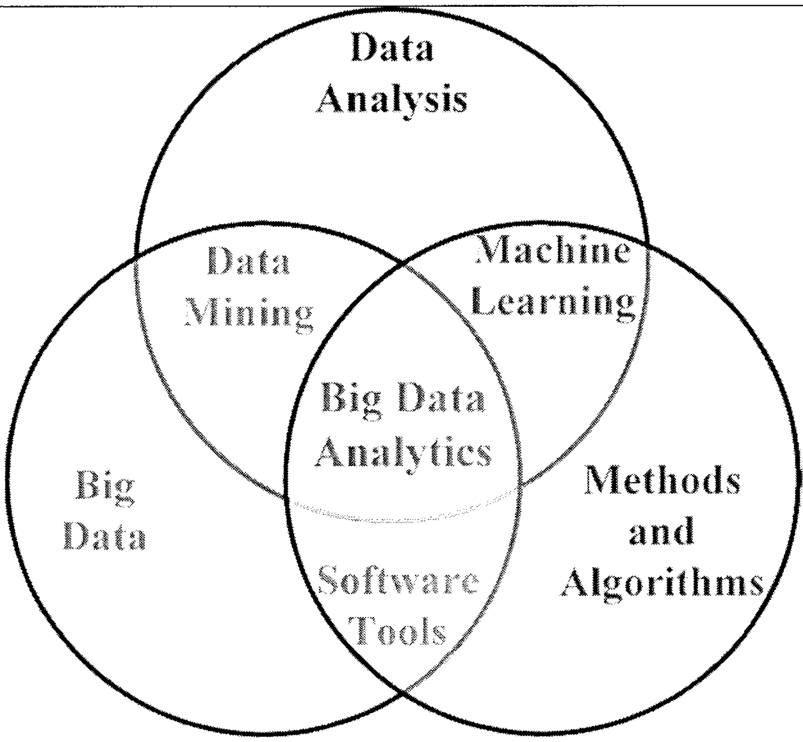
SOLUTION

Date: 26th Dec 2019
Time: 9:30 AM – 2:30PM
Max Marks: 80
Weightage: 40 %

Semester: Odd Semester: 2019 - 20
Course Code: EEE 310
Course Name: ELECTRICAL POWER GENERATION
Program & Sem: B.Tech (EEE) & 5th.

Part A (10 x 2M = 20Marks)

Q	Solution	Scheme of Marking	Max. Time required for each Question
1	• Managing Activities – Personal Banking – Similarly Electricity. • No Waiting for Monthly Electricity bills – Smart Meter Installation. • Check the Used electricity – when – cost with real time pricing – Saving money. • Managing Electricity – Home appliances- Purchase electricity – Self power generation **PRIMARY OBJECTIVES OF SMART GRIDS:** • National integration; • Self-healing and adaptive: improve distribution and transmission system operation; • Allow customers freedom to purchase power based on dynamic pricing; • Improved quality of power: less wastage; • Integration of large variety of generation options;	2M	3Min
2	• As smart grids continue to support traditional power loads they also seamlessly interconnect fuel cells, renewable, micro-turbines, and other distributed generation technologies at local and regional levels. Integration of small-scale, localized, or on-site power generation allows residential, commercial, and industrial customers to self-generate and sell excess power to the grid with minimal technical or regulatory barriers. This also improves reliability and power quality, reduces electricity costs, and offers more customer choice. • Significant increases in bulk transmission capacity will require improvements in transmission grid management. Such improvements are	2M	3Min

	• The implementation of V2G can provide frequency regulation, harmonics filtering and even failure recovery to the power system during blackout • The V2G technology can provide uninterrupted power support for home and backup energy storage for home renewable energy resources Challenges: • Battery Degradation • High Investment Cost • Social Barriers		
	Energy generation plants and transportation sector are the two major sources of carbon dioxide emission. This has reached a level that threatens the public health and environment. The deployment of renewable energy generation can help to protect the environment. However, the power generation of renewable energy sources is strongly dependent on the environmental fac- tors. The unpredictable and inconsistent energy production is the drawback of renewable energy resources. The integration of EVs in the power system can be a solution to the issues above. The intermittency issue of renewable energy resources can be solved by utilizing a fleet of EVs as energy back up so energy storages. The EV fleets act as the energy backups to supply necessary power when the renewable energy generation is in sufficient. Meanwhile, they act as energy storages to absorb the excessive power generated by renewable energy resources, which would otherwise be curtailed. Research has shown that larger renewable energy capacity can be accommodated in to the power system with more grid-connected EV battery capacity. Therefore, EV is able to improve the economics of the renewable energy generation industry. With proper energy management between renewable energy resource and EV, the future power grid will be cleaner and more sustainable	2M	3Min
7		2M	3Min

these predefined access privileges to grid devices and system functionalities reduces likelihood of malicious access to network devices. Access controls such as Discretionary Access Control (DAC), Mandatory Access Control (MAC) and Role Based Access Controls (RBAC) can increase the system reliability and eliminate potential security threats. Since IoT based SG is a cyber-physical system that is monitored and configured remotely, access controls are vital in order to limit users' and devices access in the network.

4.3.2 Encryption

When deploying IoT solutions, there is need to encrypt traffic flowing between IoT devices and the control centers including the utility provider's servers. Ensuring that the communications are encrypted using strong encryption tools is crucial as it reduces an attacker's ability to either hijack communications or generate valid data in order to fool the system. This ensures that both the integrity and confidentiality of data communications is maintained.

4.3.3 Authentication

This involves identifying devices in the network and authorizing what each device should carry out in the network. Device authentication is normally the first step of a data communication session, and its result is often a shared session key for encrypting and authenticating subsequent data packets and ensuring data integrity. Due to the time-sensitive and traffic-intensive nature of IoT smart grid communication, an authentication scheme should involve minimal exchange of messages between the grid devices. Authentication ensures meter will not accept commands from an unauthorized 3rd party. Authentication involves both identification and authorization.

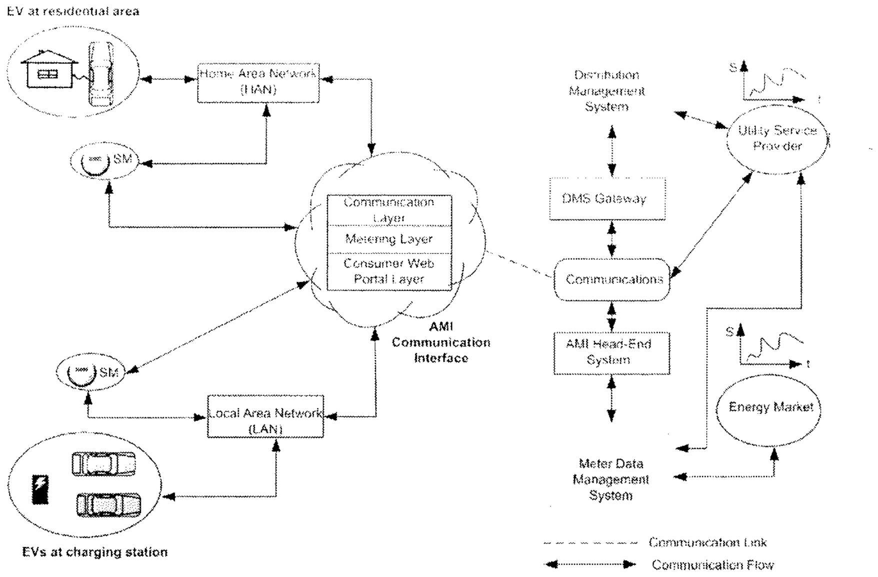
4.3.4 Regular Security Patches and Updates

IoT devices should be easily upgradable so that bugs and security updates can be deployed in an easy and manageable way. Unfortunately, most manufactures currently build devices without thinking about deploying future firmware updates at all. However, they need to appreciate that due to evolution of technology, operating systems and application code may be faced by emerging threats and vulnerabilities in future and that the rollout of updates to address these issues is paramount. Deploying firmware updates can be tricky if they're not configured to receive the updates. Considering the sheer size of an IoT smart grid, regular update to upgrade the firmware is the logical and reasonable solution as compared to a large-scale replacement of the obsolete devices. Cyber security challenges are particularly amplified when businesses integrate new and old systems without regard to overall network security. Hence, ensuring a consistent process that allows for flexible firmware deployment will allow the patching up of security loopholes across the network hence mitigating potential threats.

4.3.5 Physical Security

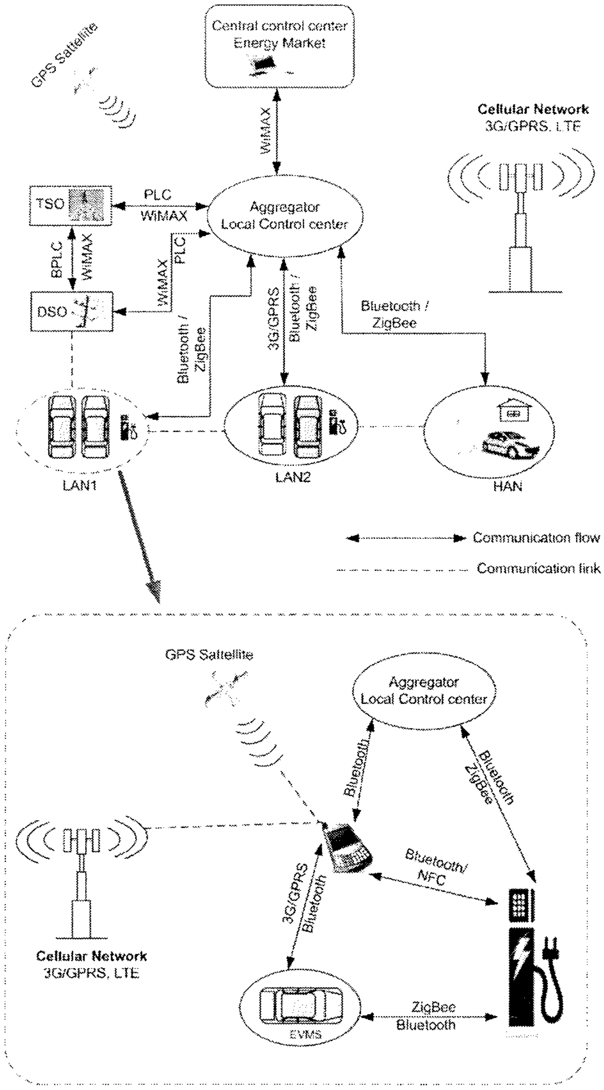
The physical security of connected grid devices is of utmost importance. Tamper-proof mechanisms should be employed and integrated into grid components to safeguard them from physical unauthorized access. The physical access by unauthorized personnel might result in data stored in the devices being compromised. Such data might include authentication, identification, usage and account information. Remote wiping capabilities should therefore be in place to erase or lock network devices to protect sensitive private data from leaking as they might be used maliciously by the intruders. Also equally important is the physical security of the premises where the servers and the control rooms are located. These provide a central location from where easy access to the whole IoT smart grid is easily available for anyone intending ill harm to the grid such as hackers and from disgruntled former or current employees. They therefore have to be secured as they pose a risk to the security of the whole network.

4.3.6 Backdoors and Logins



EV at residential area
Home Area Network (HAN)
SM
Distribution Management System
Utility Service Provider
DMS Gateway
Communication Layer
Metering Layer
Consumer Web Portal Layer
Communications
AMI Communication Interface
AMI Head-End System
SM
Local Area Network (LAN)
Energy Market
Meter Data Management System
EVs at charging station
Communication Link
Communication Flow

(b)



GPS Sattellite
Central control center
Energy Market
WiMAX
Cellular Network
3G/GPRS, LTE
TSO
PLC
WiMAX
Aggregator
Local Control center
BPLC
WiMAX
WiMAX
PLC
DSO
Bluetooth / ZigBee
3G/GPRS
Bluetooth / ZigBee
Bluetooth / ZigBee
LAN1
LAN2
HAN
Communication flow
Communication link
GPS Sattellite
Aggregator
Local Control center
Bluetooth
Bluetooth ZigBee
Bluetooth/ NFC
3G/GPRS
Bluetooth
Cellular Network
3G/GPRS, LTE
ZigBee
Bluetooth
EVMS

14

(a)

Benefits	Characteristics power requirement, response time, and storage/discharge time	Energy storage technology
Peak shaving	100 kW–100 MW, seconds to minutes, and 1–10 h	Lead-acid, Li-Ion, and Vanadium Redox Flow Batteries (VRFBs), fuel cells, ZnBr, NaS, and NiCd
Energy management	< 1 MW, milliseconds to seconds, and ~2–10 h	PHS, NaS, ZnBr, VRFB, Li-Ion, and flywheel
Load levelling	More than 100 MW, minutes, and up to 10 h	Lead-acid, SMES, Li-Ion, PHS, CAES, VRFB, ZnBr, and fuel cells
Power fluctuations	Few hundred kW, milliseconds, and few seconds	Flywheel, SMES, super-capacitor, and VRFB
T&D upgrade deferral	10–100 MW, seconds, and 1–10 h	PHS, CAES, VRFB, and fuel cells
Frequency regulation	1–5 MW, milliseconds to seconds, and few minutes to 1	NaS, Lead-acid, $NaNiCl_2$, NiCd, ZnBr, and super-capacitors
Low voltage ride through	< 10 MW, ~milliseconds, and few seconds to minute	Lead-acid, $NaNiCl_2$, Li-Ion, NaS, and super-capacitors
Loss minimization	~ 100 MW, milliseconds, and few seconds	SMES, NaS, ZnBr, VRFB, Li-Ion, and flywheel
Reliability improvement	~1 MW, milliseconds, and few minutes to ~ 5 h	Super-capacitor, SMES, lead-acid, VRFB, and NaS
Reserve application	1–100 MW, few seconds, and minutes to few hours	CAES, flywheel, VRFB, ZnBr, fuel cell, NiCd, and PHS
Demand response	< 1 MW, seconds, and ~ 1–10 h	Li-Ion, VRFB, ZnBr, flywheel, and $NaNiCl_2$
Electric/hybrid vehicles	~50 kW, milliseconds, and minutes to hours	Li-Ion, lead-acid, super-capacitors, and fuel cells

(b)

VI. FACTORS AFFECTING SIZING OF ENERGY STORAGE

There are multiple factors which decide the size of energy storage.

A. Battery degradation

The design consideration for the optimal sizing of BESS has to undertake some key battery parameters, and battery degradation is one of them. Apart from its rated life, there are other factors which deteriorate the battery capacity.

1. Depth of discharge

Depth of discharge (DOD) represents the amount of capacity used by the battery relative to its total battery capacity. DOD is a major factor in the lifespan of the battery as it allows for deep charge/discharge cycles. Unlike sodium sulphur batteries which can bear 100% DOD, the lifetime of other battery chemistries will be severely impacted by the DOD value. The optimal DOD should be selected to increase the efficiency and longevity of the battery. The relationship between the lifecycle and DOD is normally presented in a curve which varies across different battery types. A typical curve is shown in for the lithium ion battery at a temperature of 20°C.

2. Battery lifetime

The lifetime of the battery is the most important factor in the cost operation of BESS. The number of lifecycles a battery can sustain in its entire life depends on the charging and discharging schedule of the battery. The lifetime degradation of the battery is affected by two main factors; the lifecycle aging reflecting the number of cycles that the battery has accomplished and the decrease in battery capacity. The lifetime equation varies with the type of battery used. However, it can be extended with a proper selection of the depth of discharge and cycle depth.

3. Temperature

The degradation of the battery life is dependent on the ambient temperature by a phenomenon called capacity fading. It analyses the reduction in the total capacity of the battery operating at a certain temperature after it experiences a particular number of charging and discharging cycles. This phenomenon has been observed at both high and low temperatures to evaluate its impact on the performance of the battery. The internal resistance of the battery increases at low temperature, whereas battery chemical reaction increases at high temperatures, which degrades the electrodes. The capacity fading percentage changes with the battery characteristics provided by the manufacturers.

4. Charge and discharge current

Another factor constituting the battery degradation is the charge and discharge currents. The high current during charging and discharging operation negatively affects the battery lifespan. The battery capacity also reduces when supplying large currents due to the increase in the internal resistance. Thus, charge and discharge power should be limited to specific values to avoid the damage of BESS.

B. Reliability

The reliability of the microgrid is essential for determining the optimal size of energy storage. The reliability criteria should satisfy the reliability indices available in terms of generation adequacy and economic factors. The energy storage provides feasible solutions for satisfying the microgrid reliability levels efficiently. Load curtailment and load leveling are viable options to achieve the reliability indices in the microgrid.

C. Battery placement

Research into the optimal placement of BESS in a microgrid is still at its infancy. To minimize the losses and improve system stability, energy storage must be allocated appropriately. The optimum location may lead to reduction in the energy purchased from the main grid, which decreases the cost of the microgrid. The optimal storage location which can support the high penetration of RES is selected by performing tests for different scenarios.

5+5=10M

15M

(b)

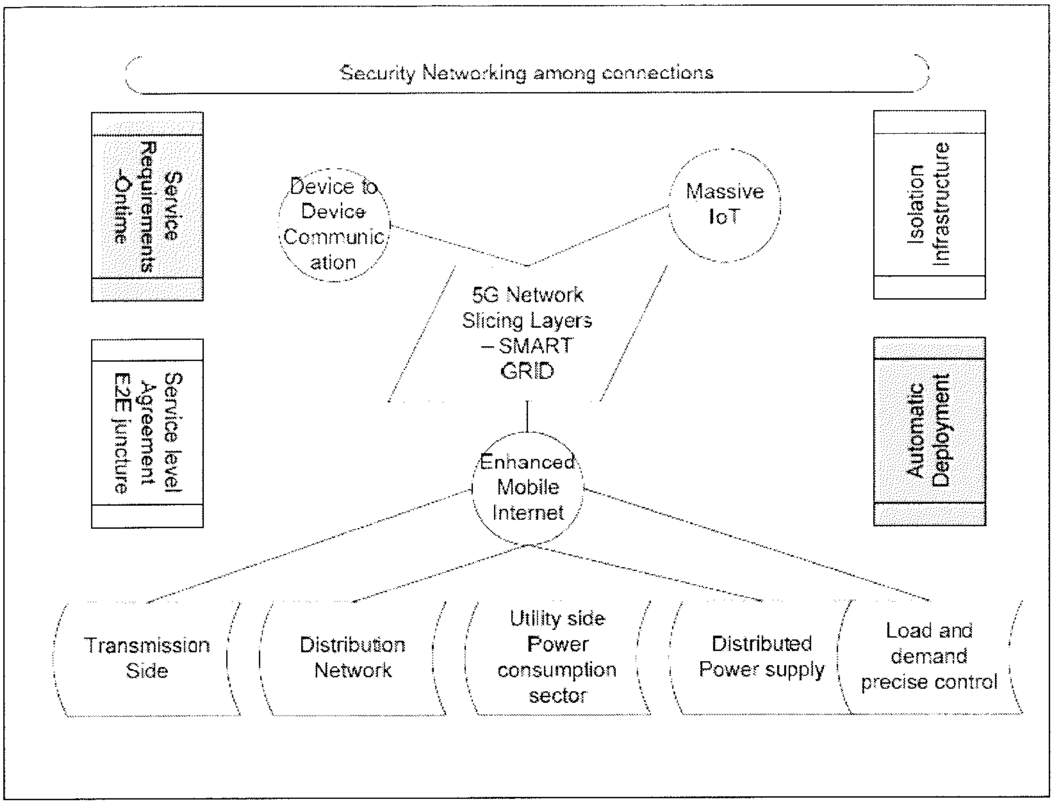


Figure 3. Roadmap architecture of 5G and smart grids.

(c)

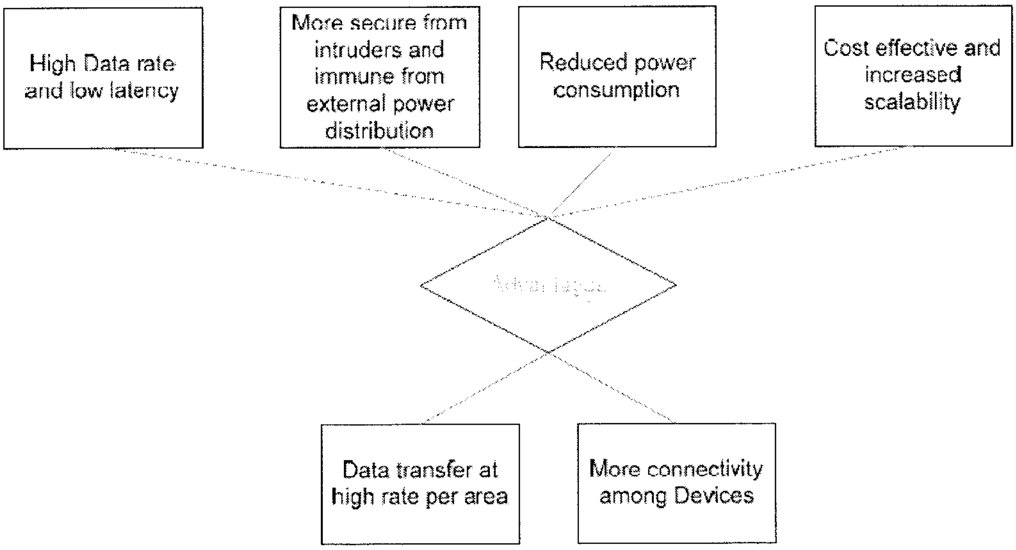


Figure 5. Benefits of 5G networks in smart grids.