Viet Nam Energy Partnership Group

Ministry of Industry and Trade

Hợp tác Đức
DEUTSCHE ZUSAMMENARBEIT

Implemented by
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ERAV Electricity Regulatory Authority of Vietnam

Toward 100% Renewable Energy
100RE LAB

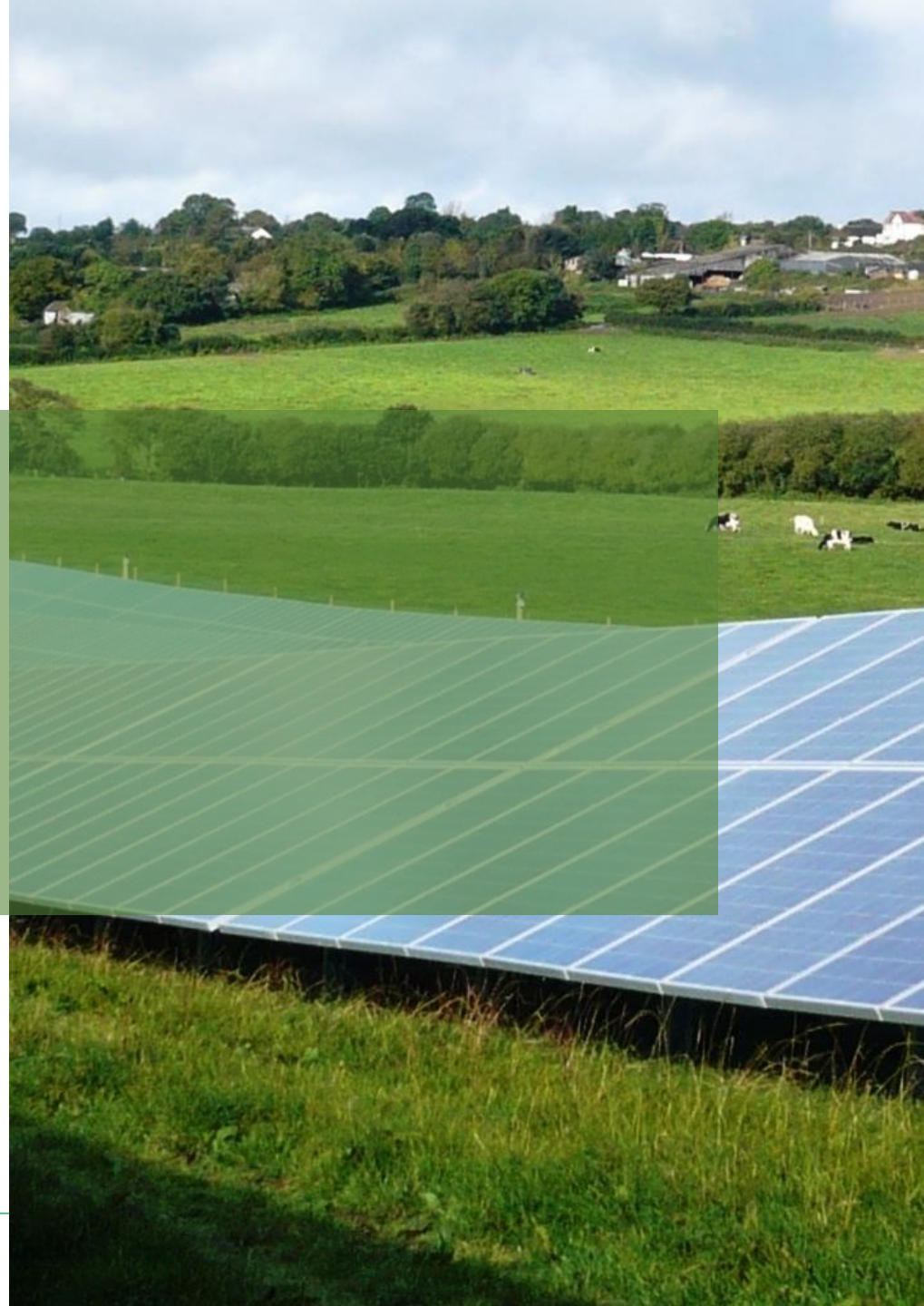
VEPG Technical Working Group 3 Meeting, 27&28 June 2022, Hue

Smart grids: International development trends and potential solutions for VN

Presenter: Dr. Nguyen Duc Tuyen

Outline

1. Smart Grid Perspective
2. Vietnam Smart Grid Fact
3. Smart Grid Research Topic Trend
4. Discussion and Recommendation
5. Conclusion



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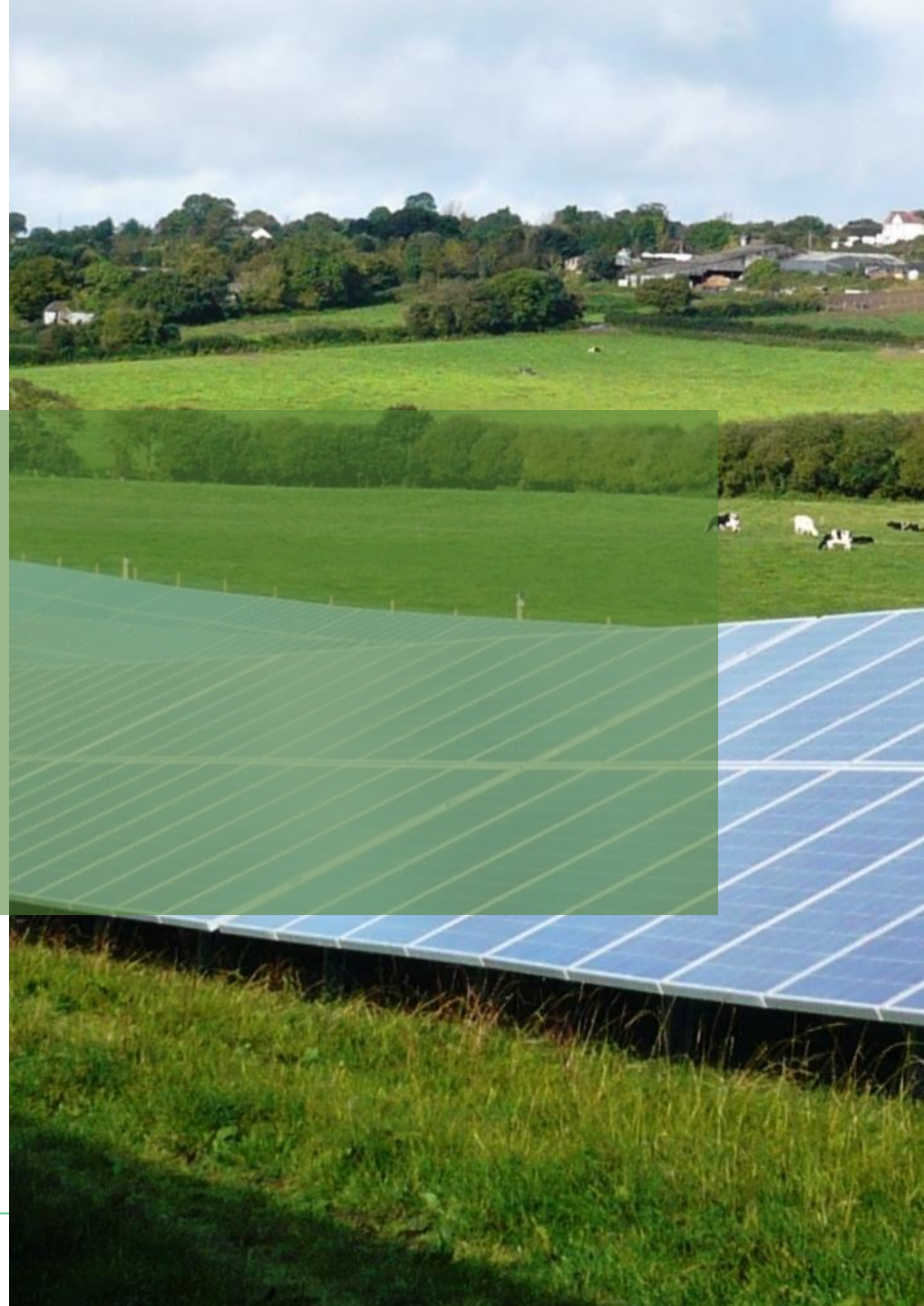
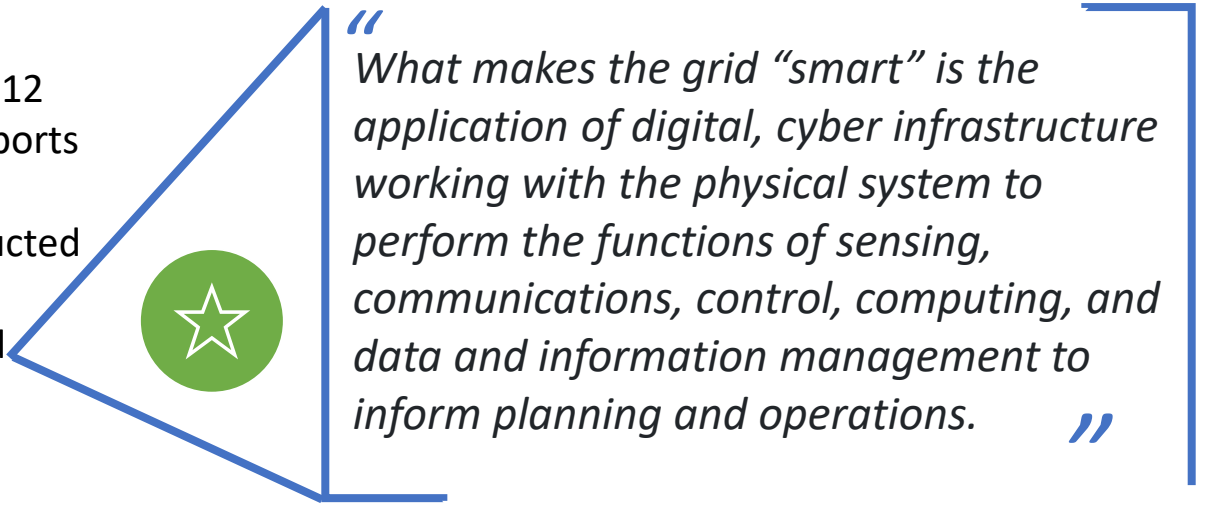


Smart Grid perspective

Smart Grid Circumstance

- Number of motivations for enhancing Smart Grid
- Plenty of research papers and conferences during 2011, 2012
- Smart Grid mentioned again from 2020 with number of reports
- Grid development is gradually an obvious smart grid one
- Smart Grid test best and demonstration projects are conducted prevalently worldwide
- ICT, IoT, BlockChain, AI experts are involved into Smart Grid research



"What makes the grid "smart" is the application of digital, cyber infrastructure working with the physical system to perform the functions of sensing, communications, control, computing, and data and information management to inform planning and operations."

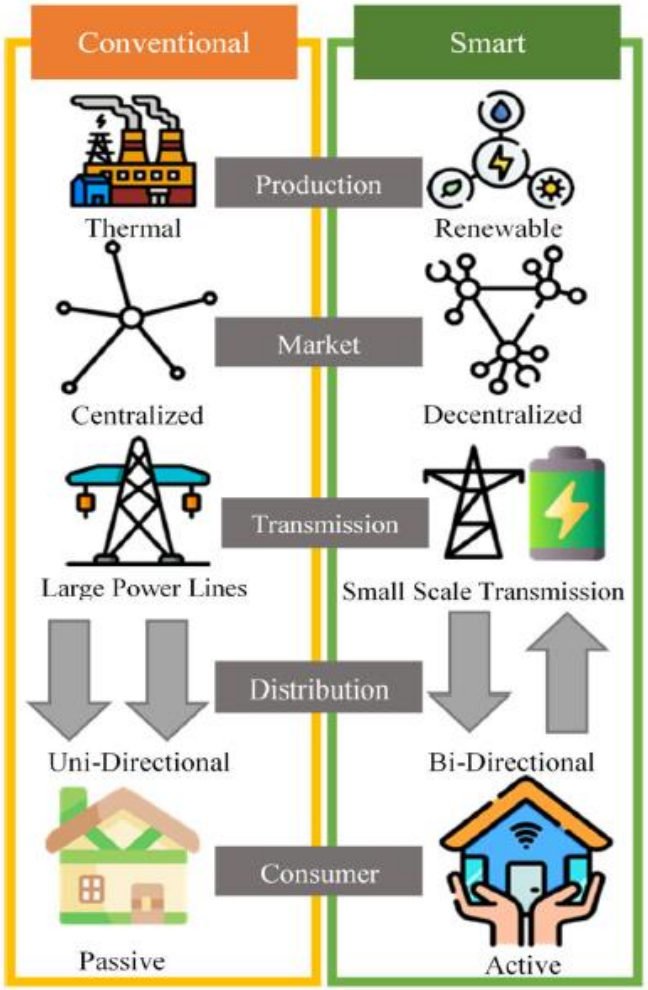
Portfolio Sources

1. IEEE Transactions Smart Grid
2. IET Transactions Smart Grid
3. IEEE Power and Energy Magazines
4. IEEE Access
5. IEEE Proceedings
6. Elsevier Transactions
7. IGST Asia, IGST Europe Conferences
8. Worldwide Reports on SG Implementation

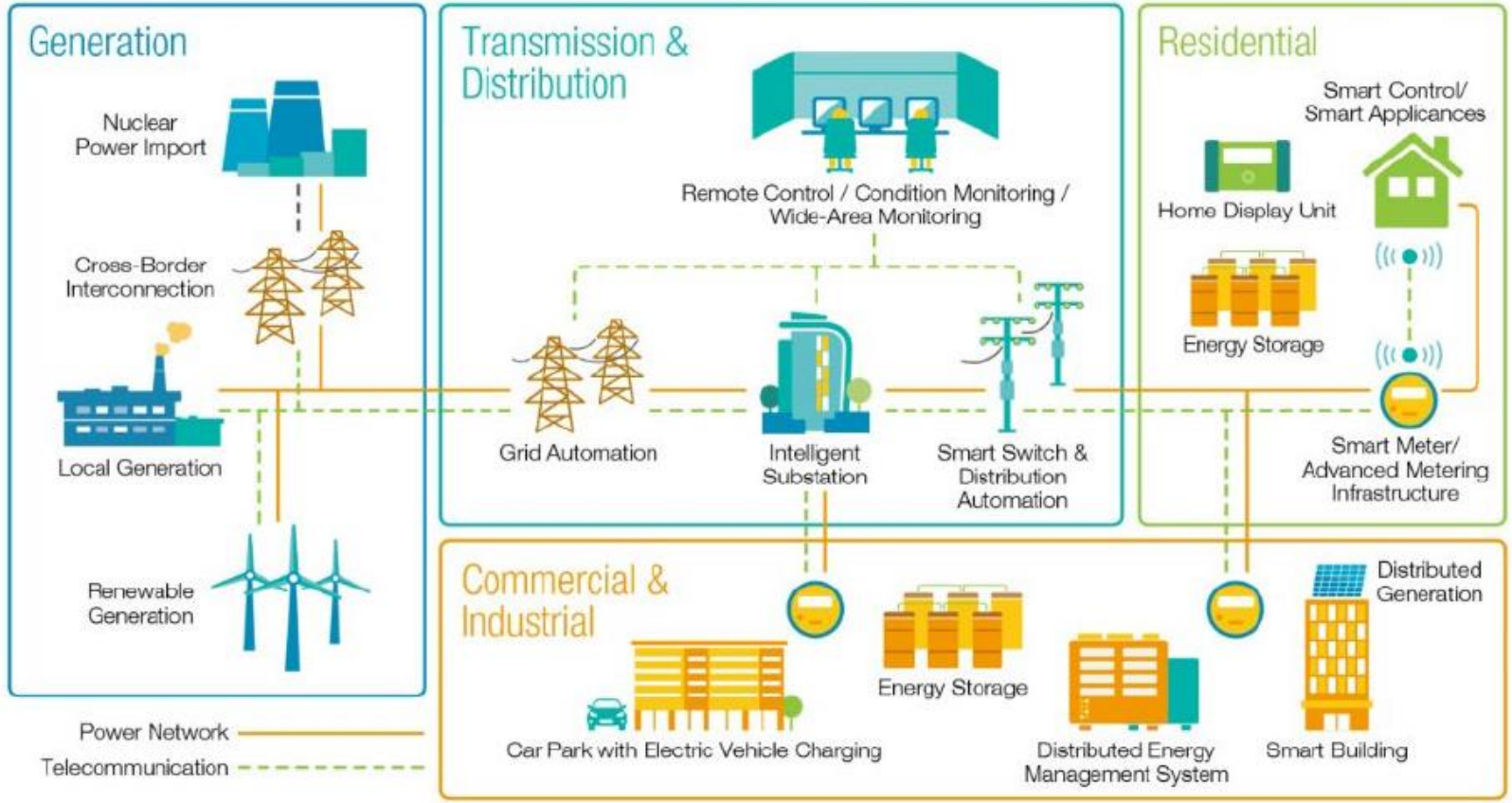
"An electric platform that will ensure an ability to improve aspects such as resilience, security, efficiency, and affordability while addressing uncertainty for future technological options and changing customer preferences and policies."

What is smart grid?

COMPARISON



SMART GRID TECHNOLOGIES ACROSS THE POWER SYSTEM



New Technologies → Enable Flexibilities

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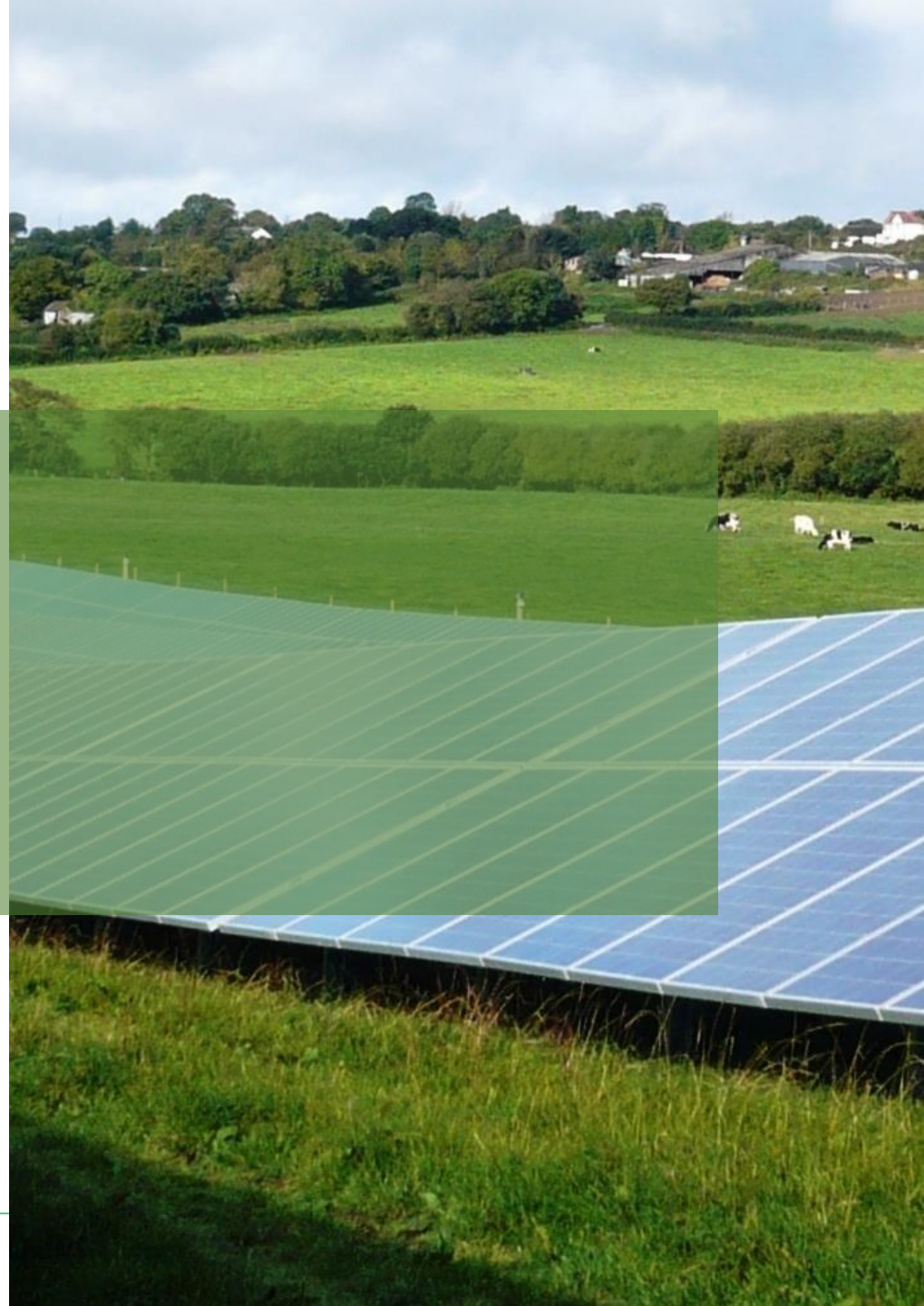
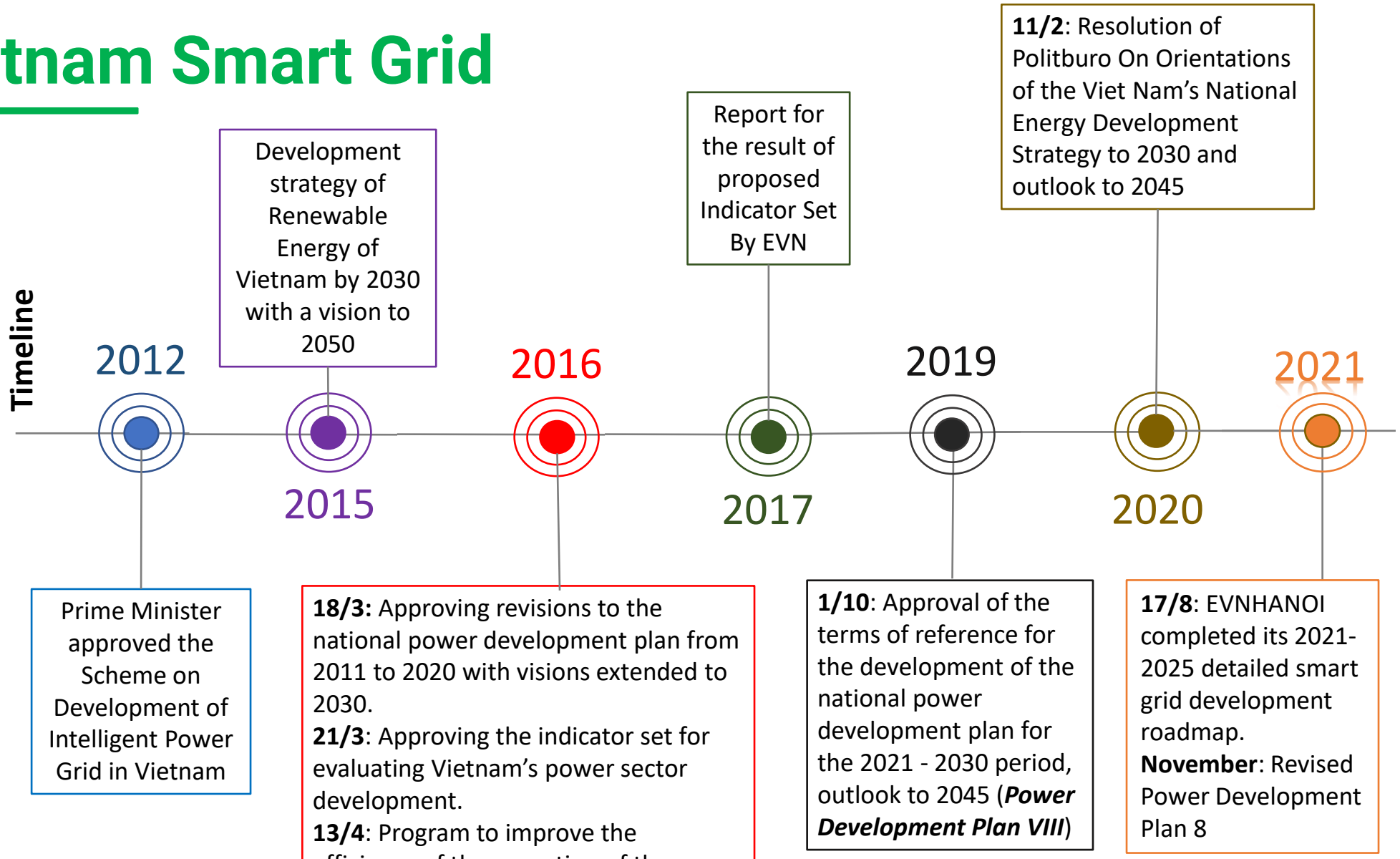


Vietnam Smart Grid

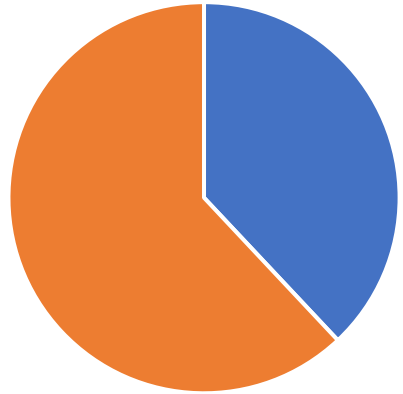


Vietnam Smart Grid

SCADA CONNECTION RATE

Power Plant / Substation	Year		Total Amount	Connected	Remaining connection	Connected and sufficient signals
Power Plant (> 30MW)	12/2019	Quantity	222	222	216	199
		%		100%	97%	90%
	12/2020		276	276	270	245
				100%	98%	89%
Substation 500kV	12/2019	Quantity	32	32	32	29
		%		100%	100%	91%
	12/2020		36	36	36	33
				100%	100%	92%
Substation 220kV	12/2019	Quantity	134	134	134	132
		%		100%	100%	98,5%
	12/2020		140	140	138	139
				100%	99%	99%
Substation 110kV	12/2019	Quantity	841	806	763	609
		%		96%	91%	72,4%
	12/2020		869	844	825	756
				97%	95%	87%

Remote meters at 110kV+ substations



Mechatronic Meter Digital Meter

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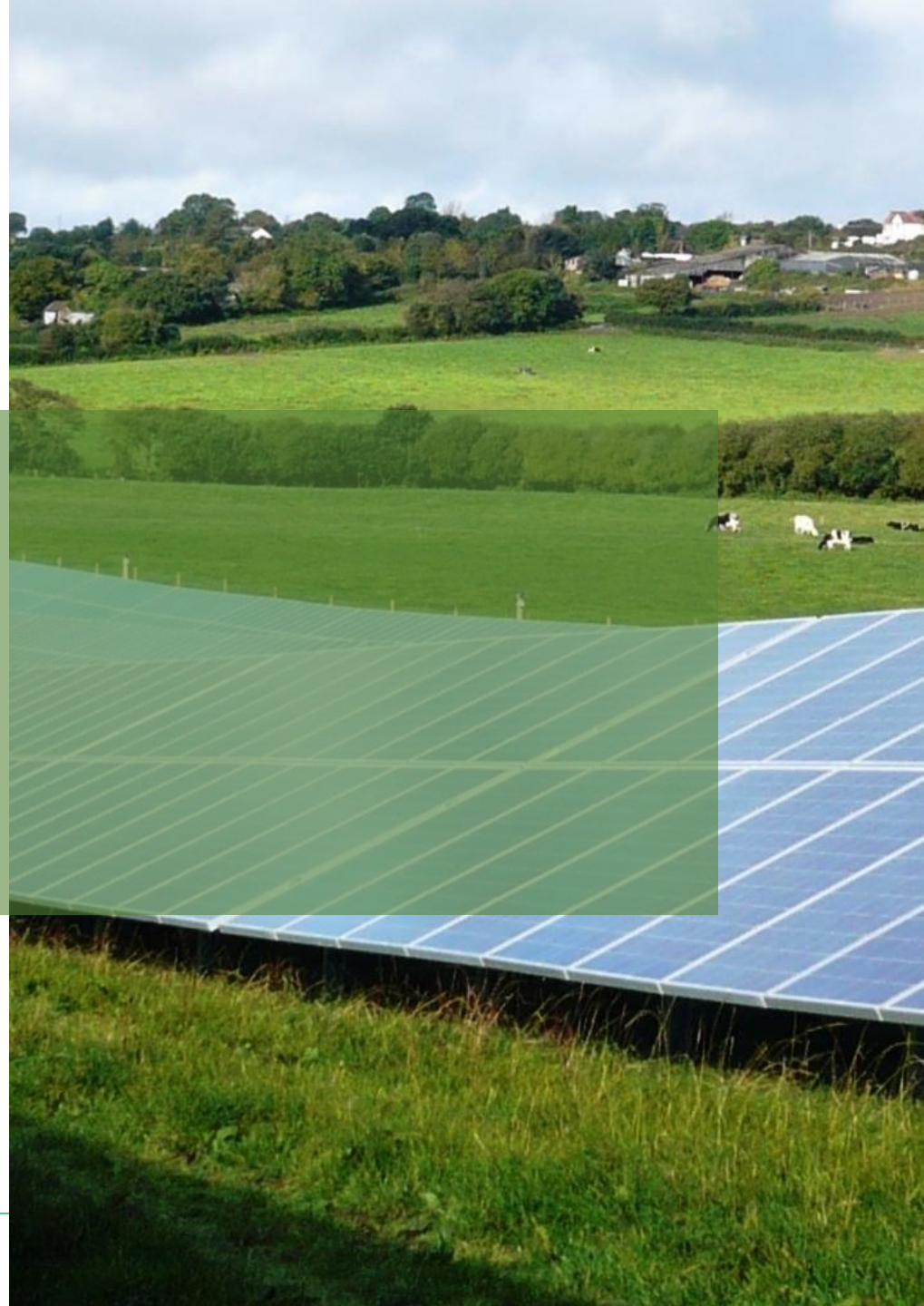
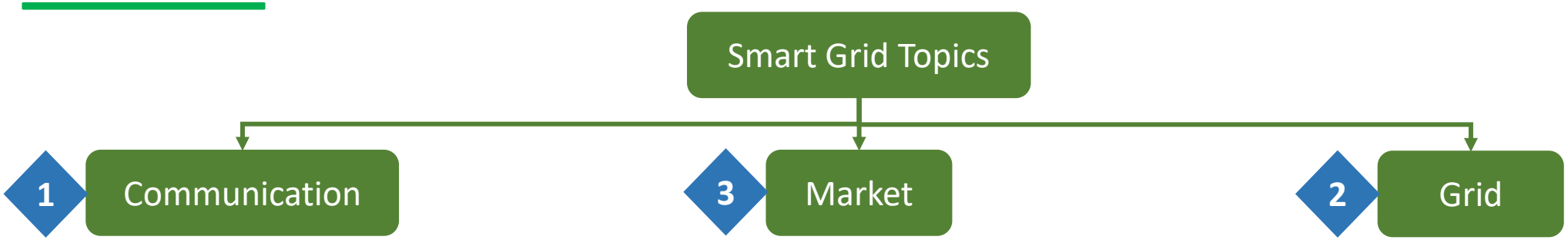


Smart Grid Research Topics



- Smart Meter Infrastructure
- Wide area monitoring
- IoT Service
- Communication Standards
- Cyber Attack
- Data Management
- Secure, Robust Communication
- 5G, wireless

- Prices Forecast
- Block chain, Smart Contract
- Peer-to-Peer Energy Trading
- Power, Load Forecast
- Electricity Theft
- Varied Load Impact
- EV Smart Charging
- Smart Home Applications

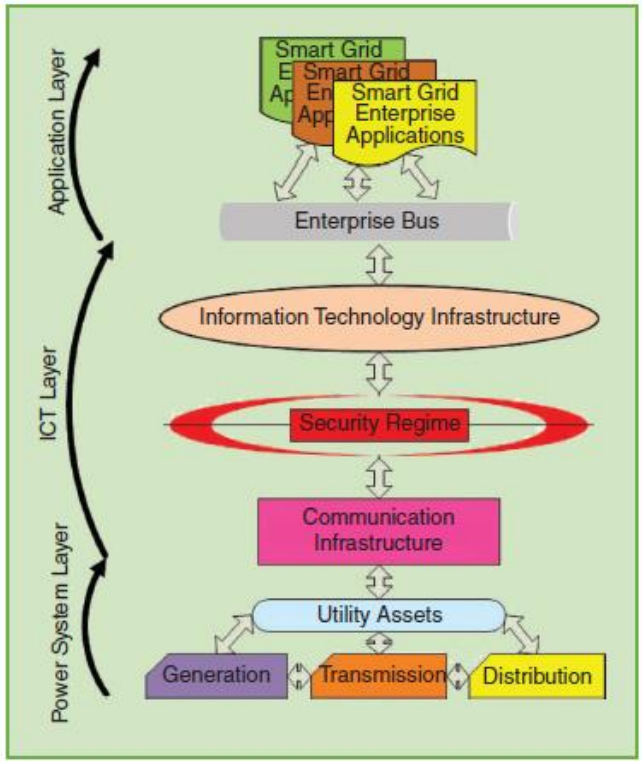
- Grid Resilience, Robustness, Uncertainty
- Optimization, Multi-agent Control
- Energy Storage Management
- Smart Wide Area Protection
- Stability, Life Estimate using AI
- Smart Transformer and Transmission
- Forecast (Power, Fault)
- Flexible, Interconnect AC-DC grid

01

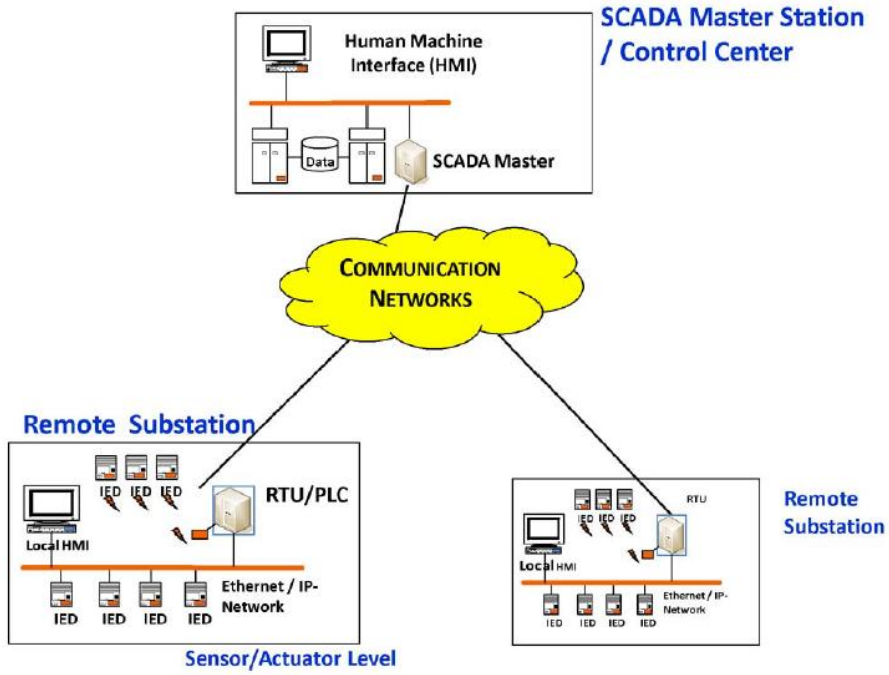
COMMUNICATION

Toward 100% Renewable Energy

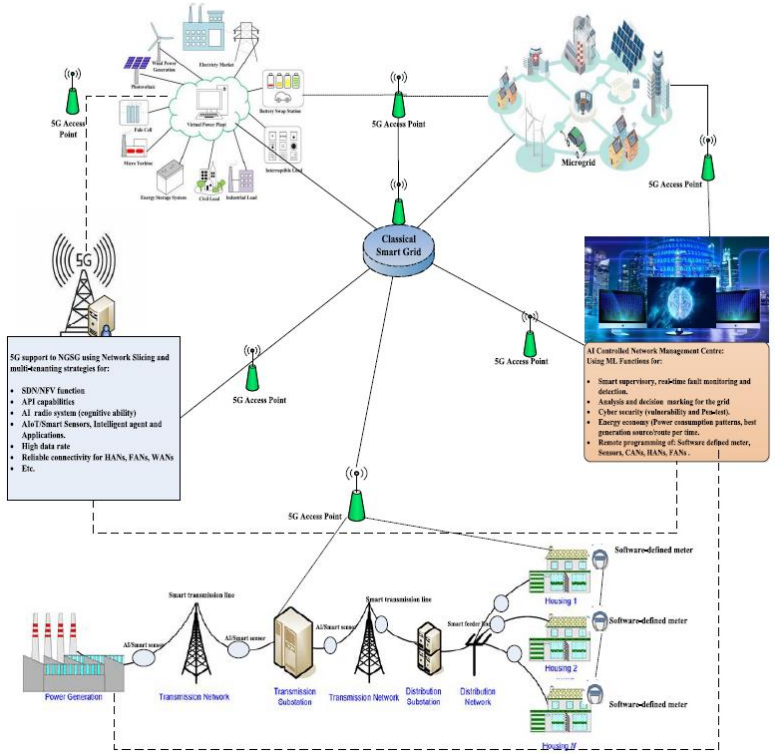
Smart Grid Communication Systems



A hierarchical smart grid system integration map



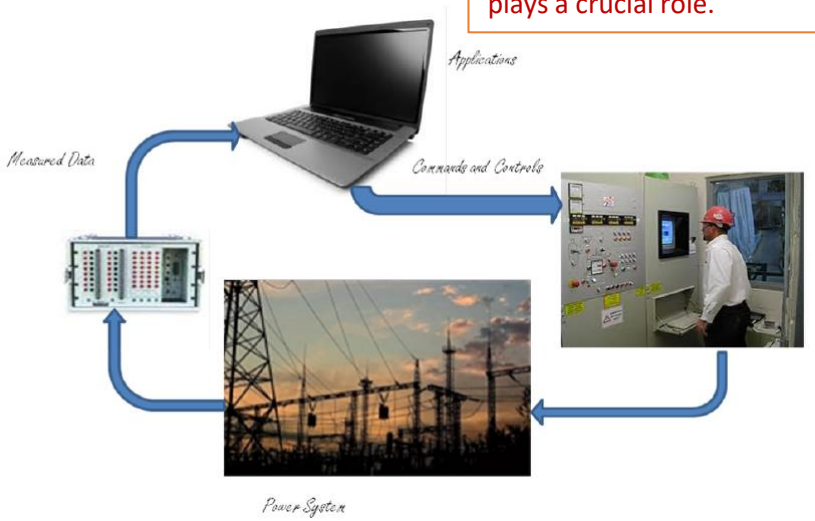
Power grid SCADA system



Network architecture for the next generation smart grid

Data-driven Operating Power system

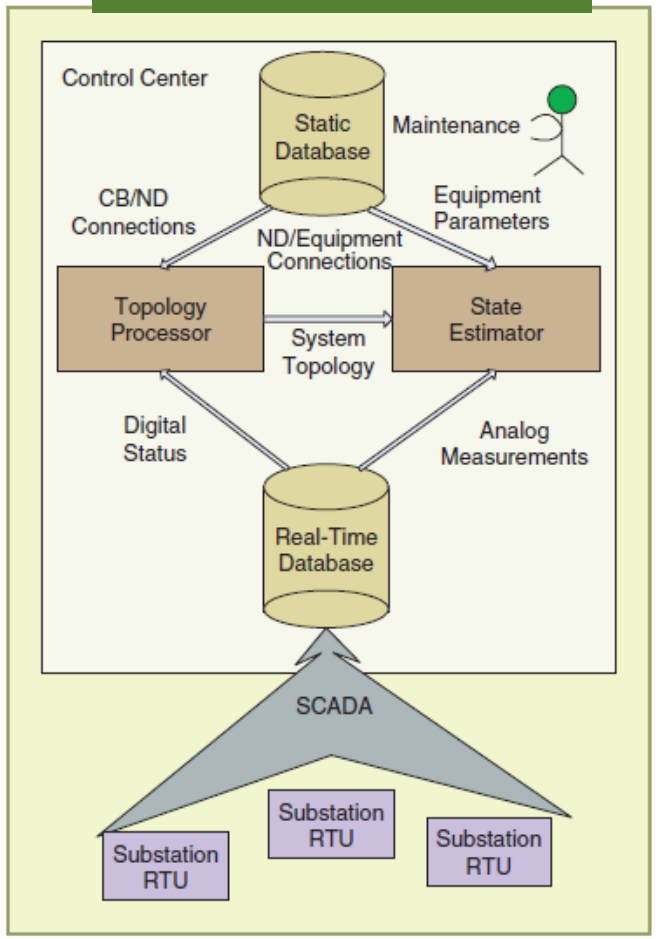
> In developing a smart grid, the measurement technology used plays a crucial role.

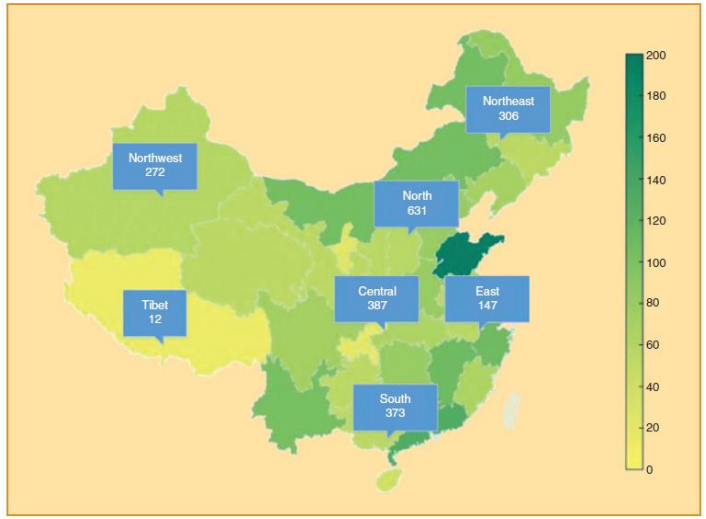


Closed loop system for smart monitoring and control of power system:

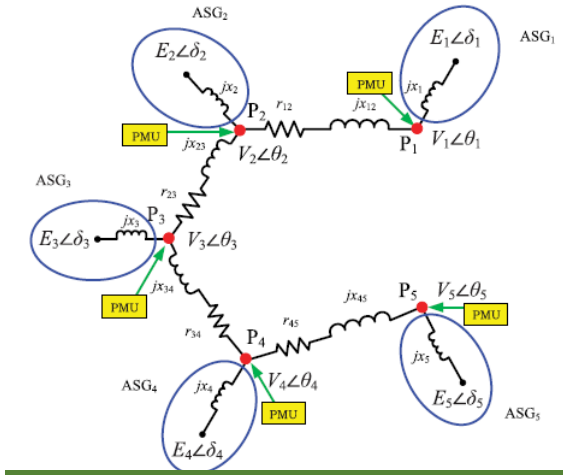
- *Measurements and Sensing*
- *Communication*
- *Processing Equipment and Programs*
- *Acting on the System Based on Obtained Information*

The two-level linear state estimator





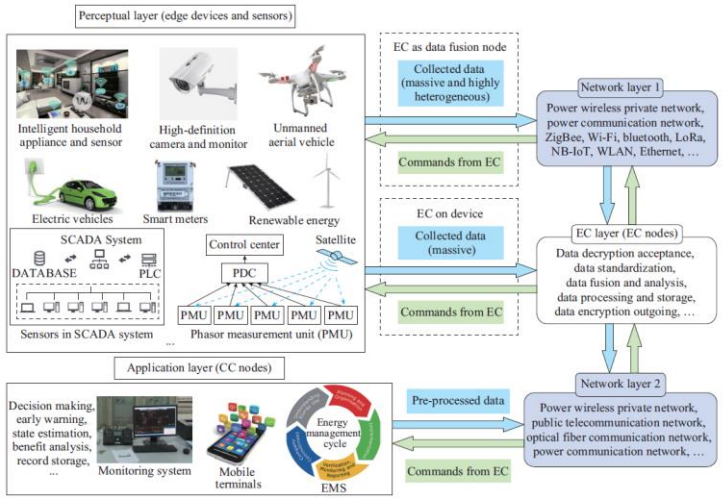
PMU deployment in China as of 2012



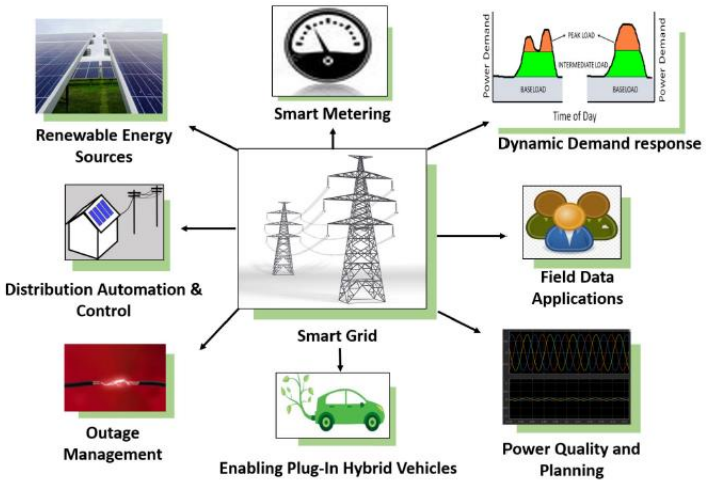
Model aggregation for simulation applied in wide-area measurement system (WAMS)

Smart Grid Data Flow & Analysis & Managemnet

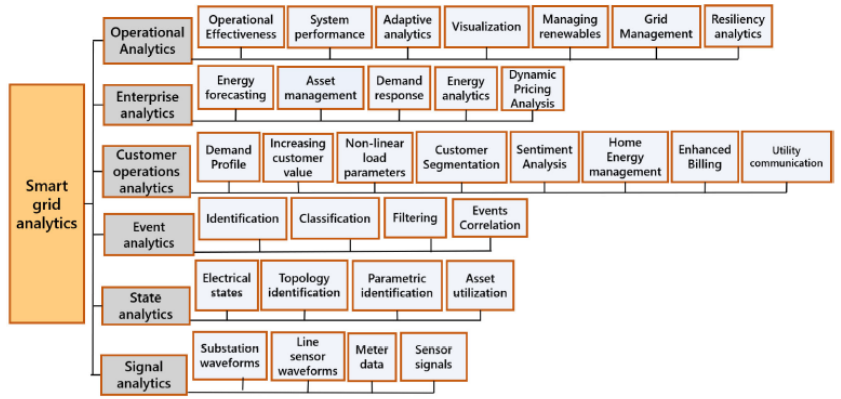
Integration of edge computing (EC) to existing cloud computing (CC) system/ centralized control for data storage and processing serves real-time operation and control



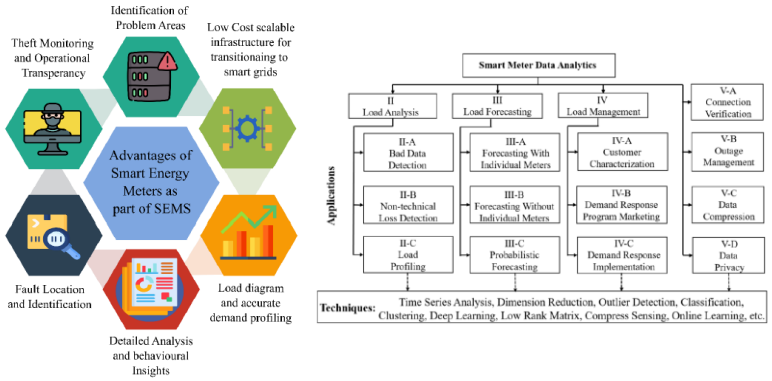
A comprehensive architecture of EC-CC system in smart grid



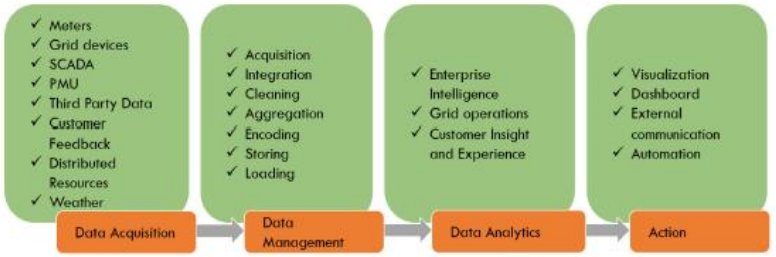
Smart grid as enabling engine - depiction of opportunities



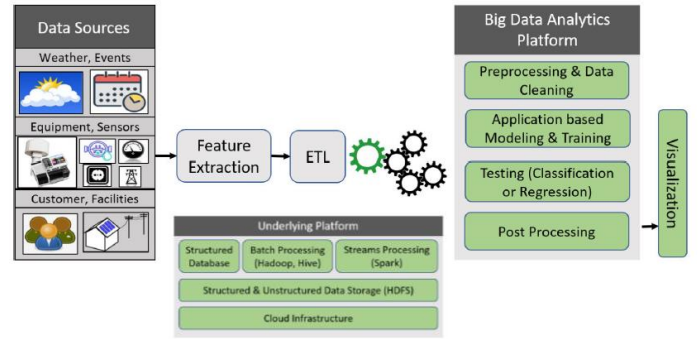
Scope of big data analytics in smart grid



SM in Smart Energy Management Systems (SEMS)

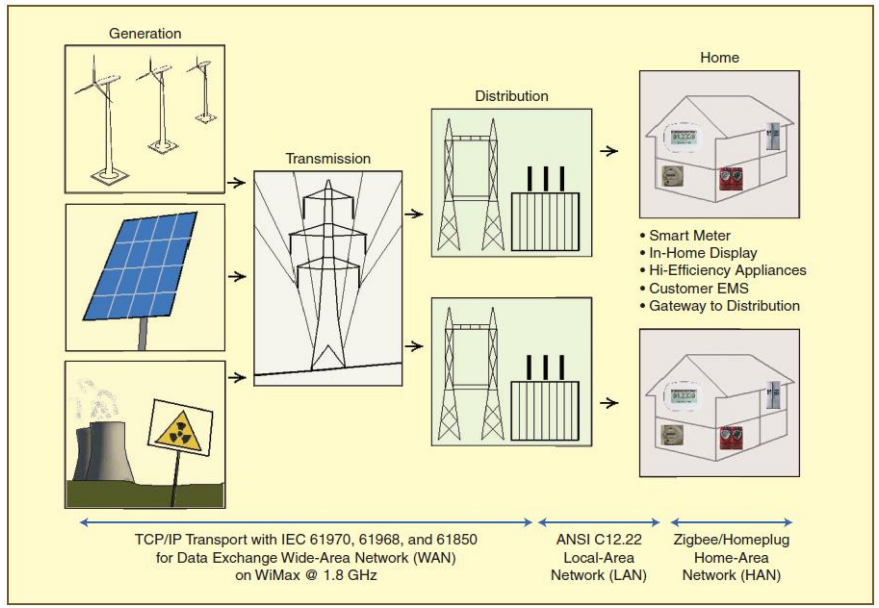


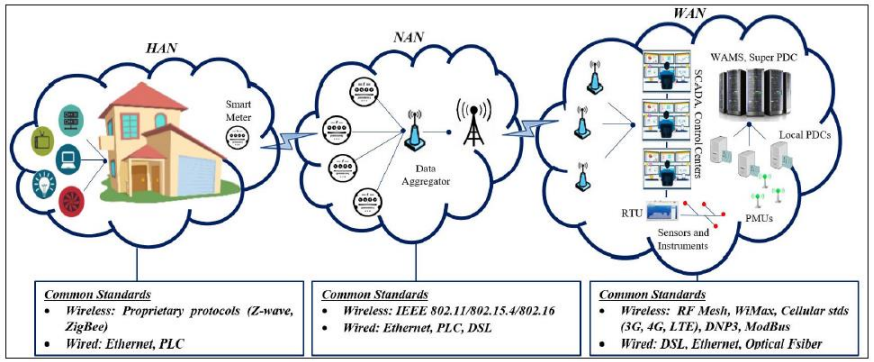
High-level view of the flow of data into the utility



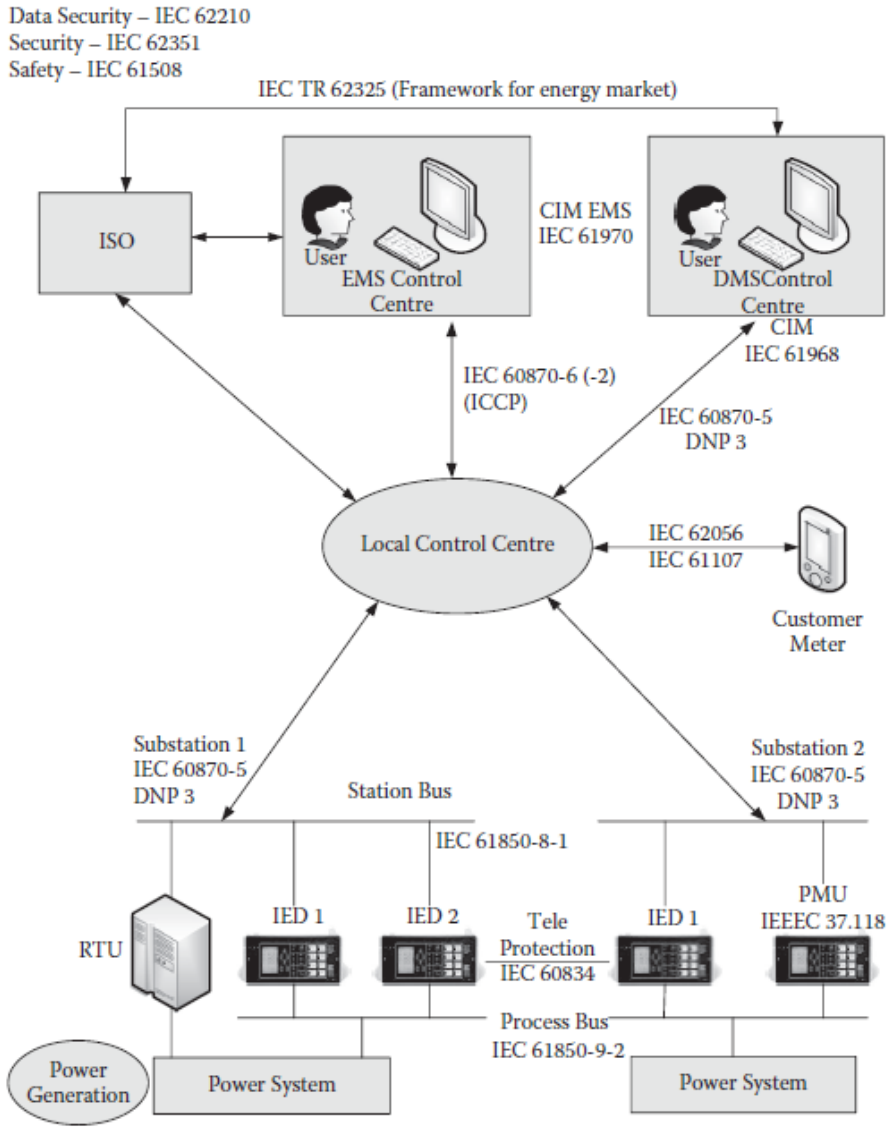
Big data analytics process

Smart Grid Standards



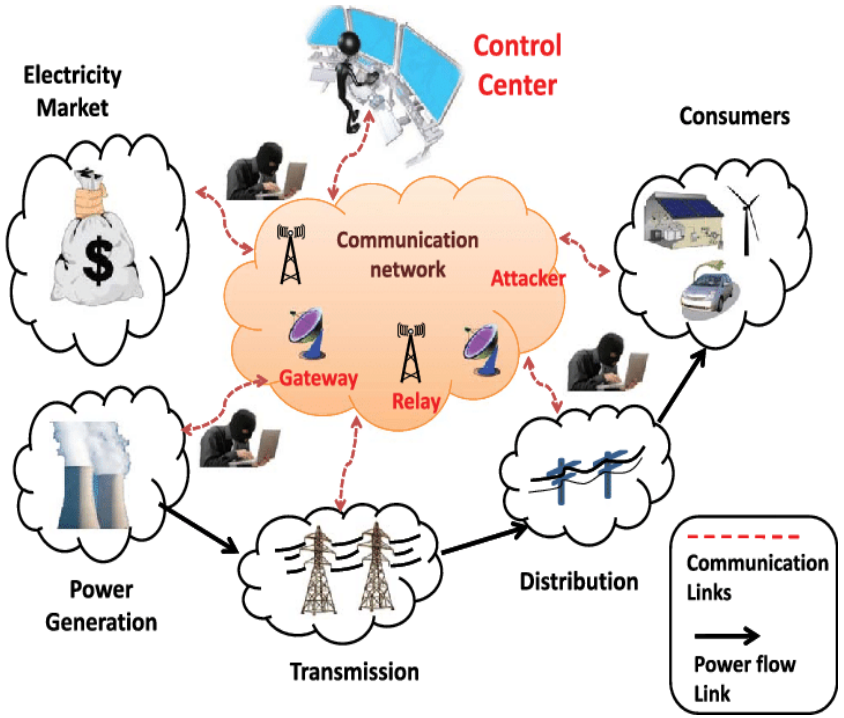


Main data communication standards

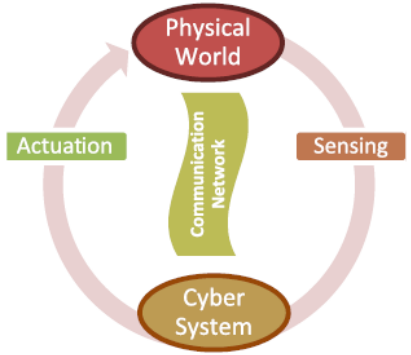


SCADA and smart grid protocols

Smart Grid Security (1)

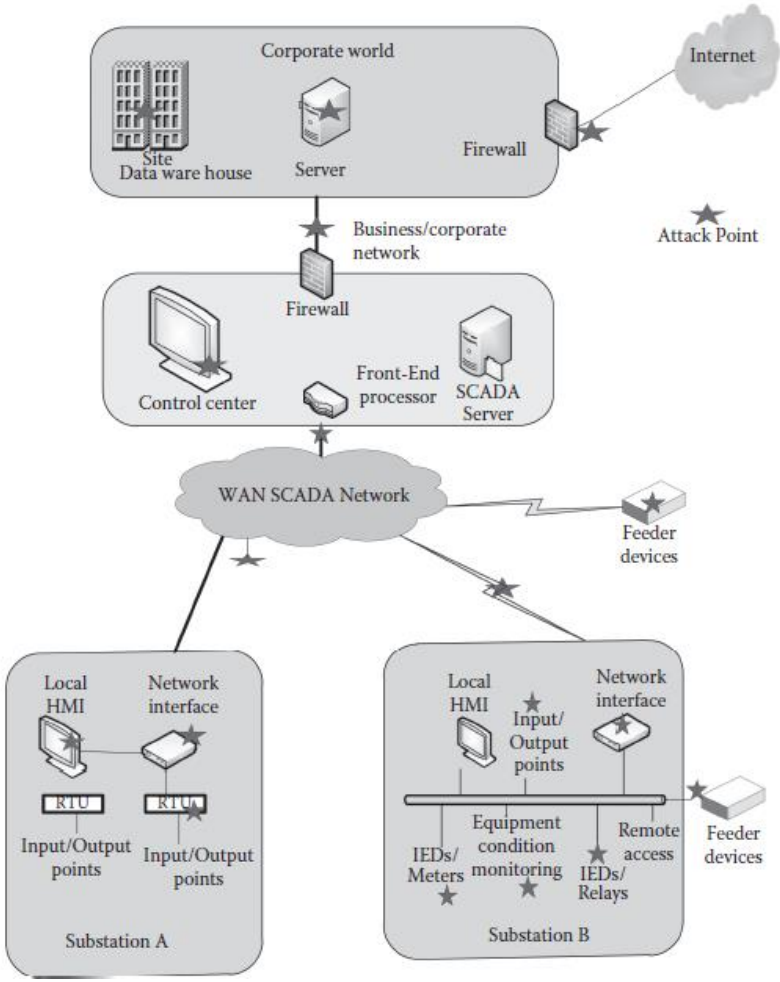


Cyber attacks have the potential to threaten multiple layers of the cyber-physical system of the grid



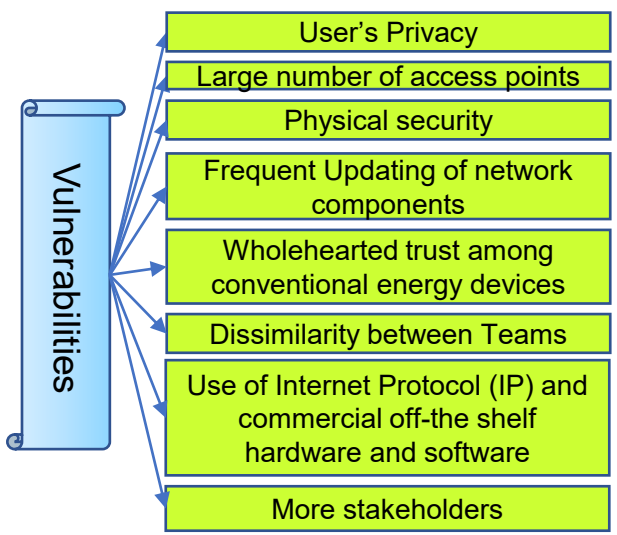
Cyber–physical systems

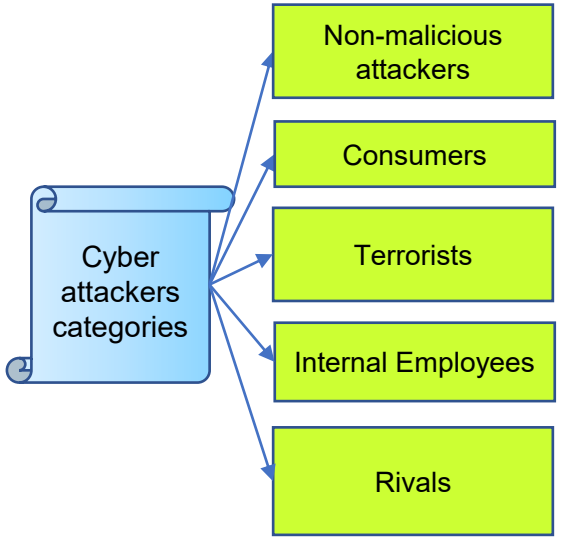
Cyber Security of Data and Power Systems (EVNCPC Quang Nam)

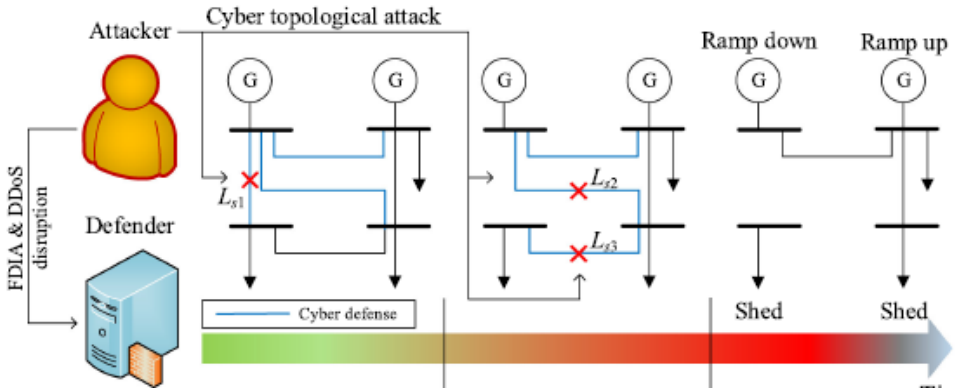


Security threat points in a SCADA network

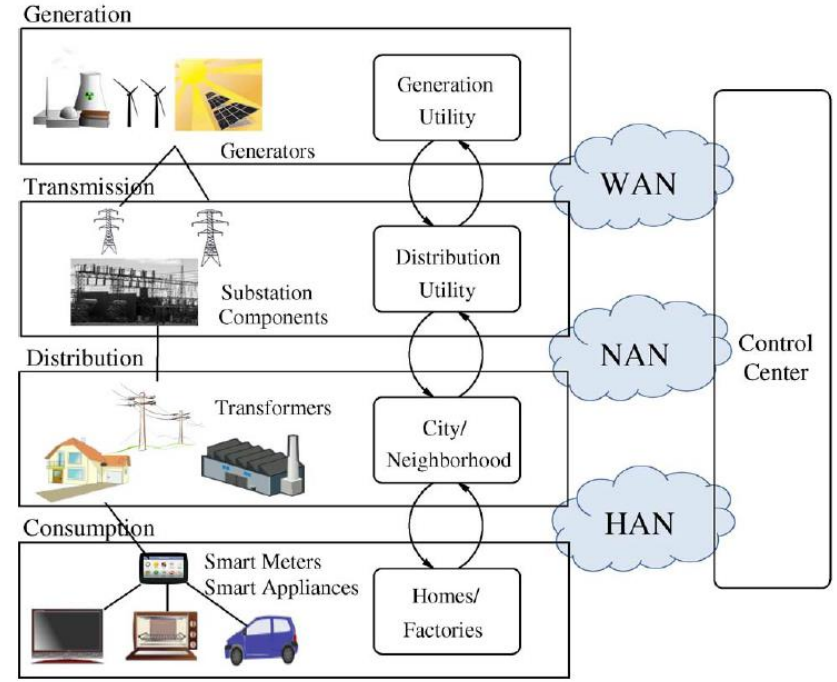
Smart Grid Security (2)



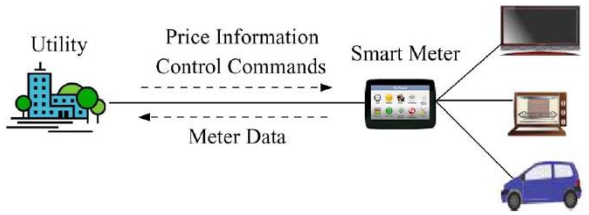




Cyber-physical risk mechanism



A cyber security view of smart grid

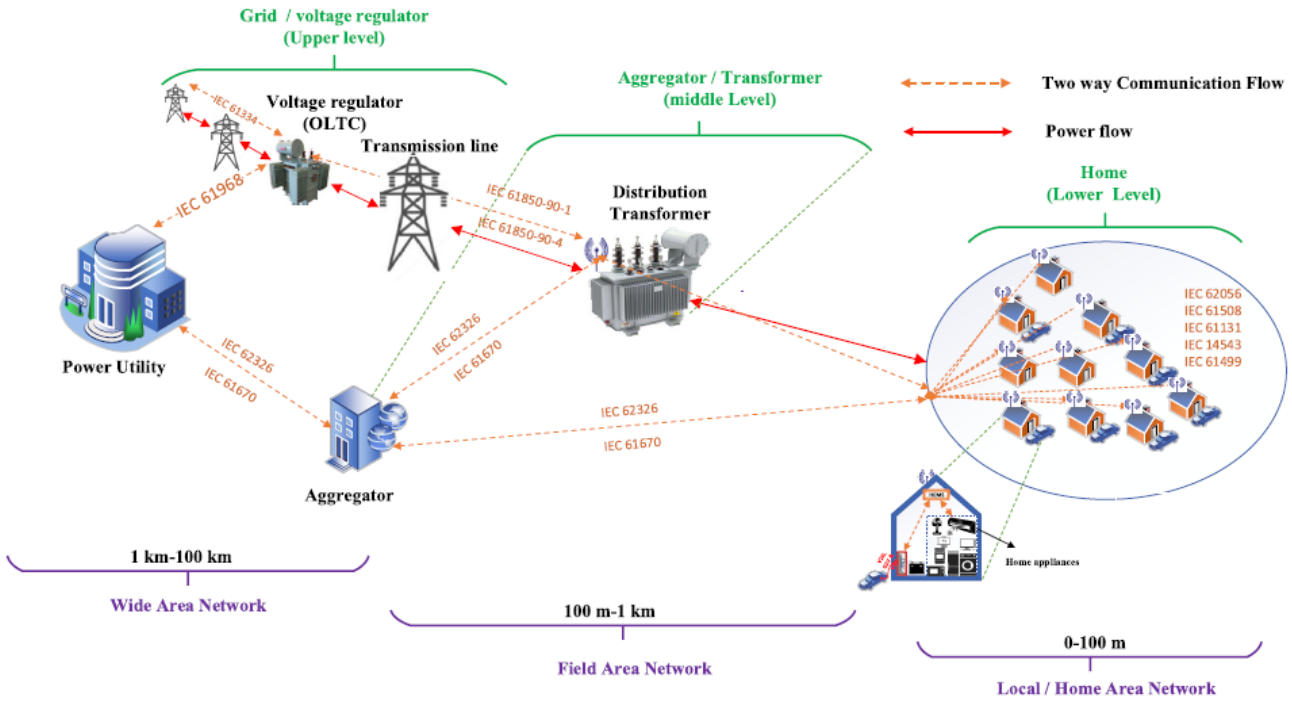


Information flows to/from a smart meter including price information, control commands, and meter data

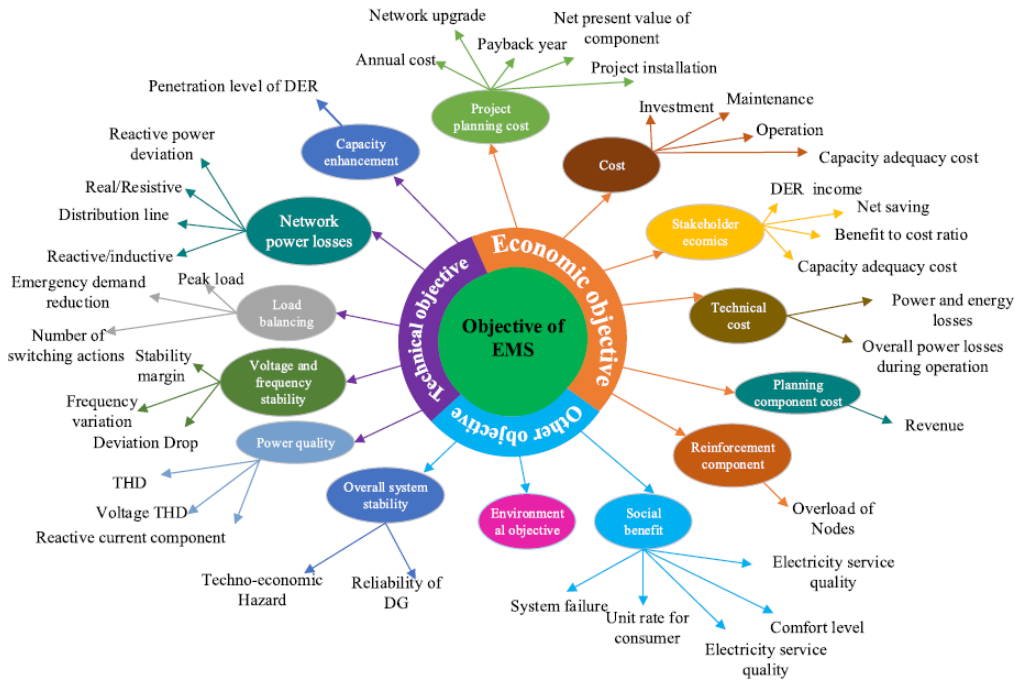
02

GRID

Control Architecture of Energy Management System (EMS)



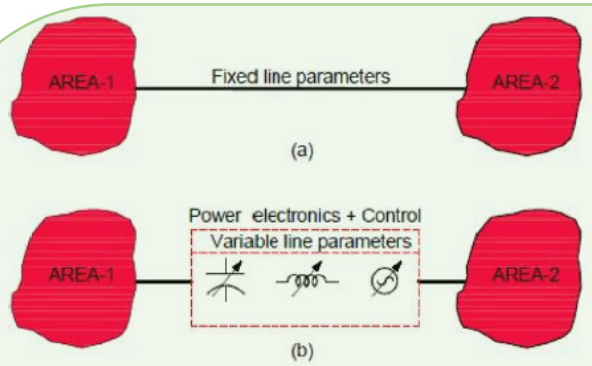
Conceptual architecture overview of different level of EMS



Technical and economic objectives of EMS at different level

Flexible AC Transmission Systems (FACTS) & Resilient AC Distribution Systems (RACDS)

Traditional FACTS and RACDS devices: (a) TCR, (b) TSC, (c) TSSC, (d) TCSC, and (e) multi-pulse converter



Role of power electronics in FACTS: (a) Transmission network without FACTS and (b) transmission network with FACTS.

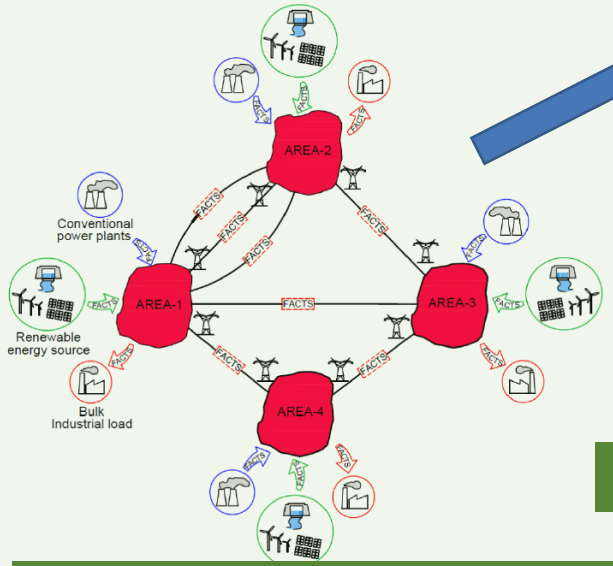
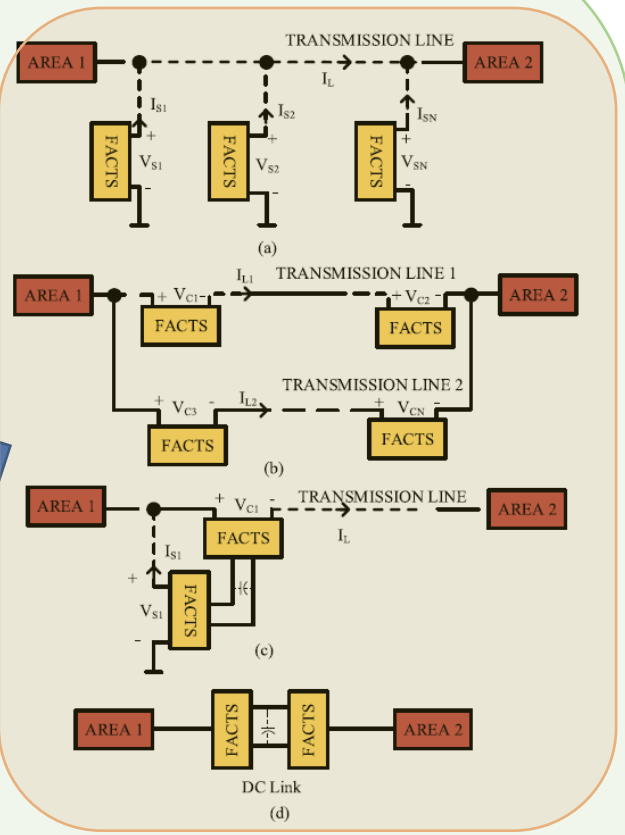


Illustration of the transmission network in a smart grid



Different configurations of FACTS for smart-grid:
(a) shunt, (b) series, (c) series-shunt, and (d) back-to-back

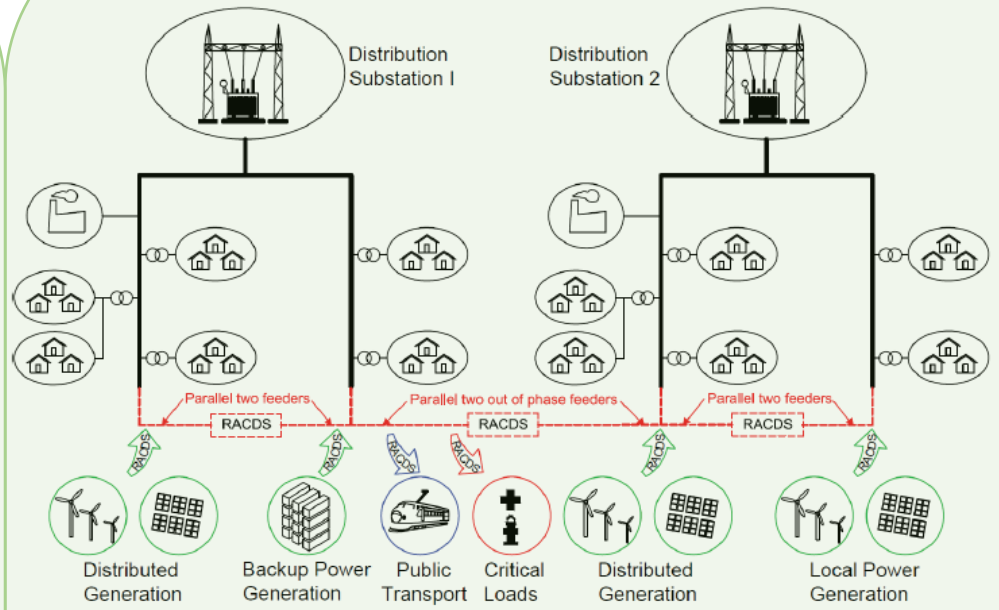
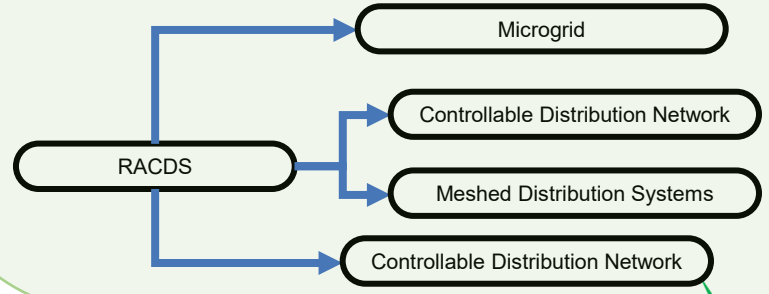
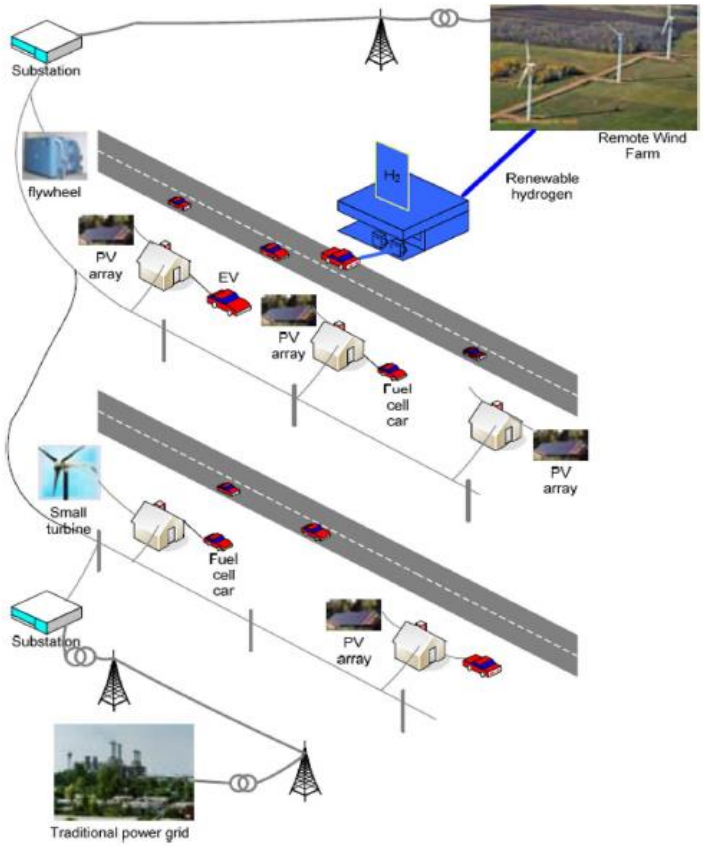


Illustration of the distribution network in a smart grid

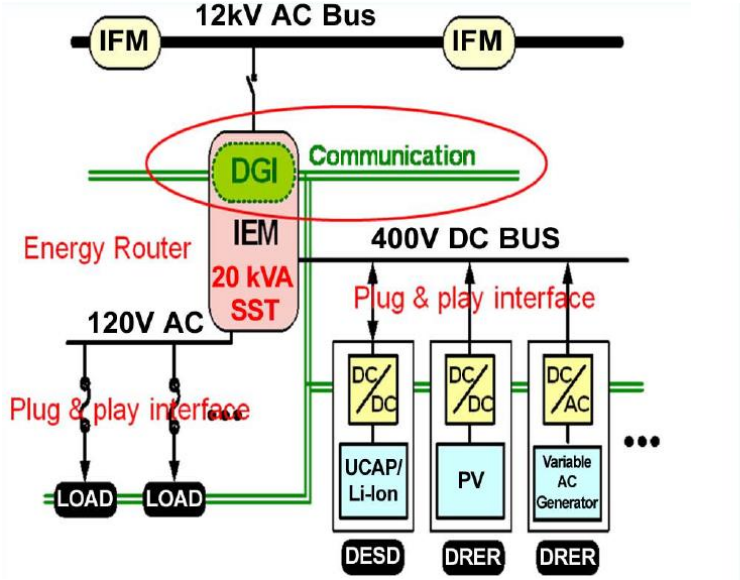


Distributed Renewable Energy Integration

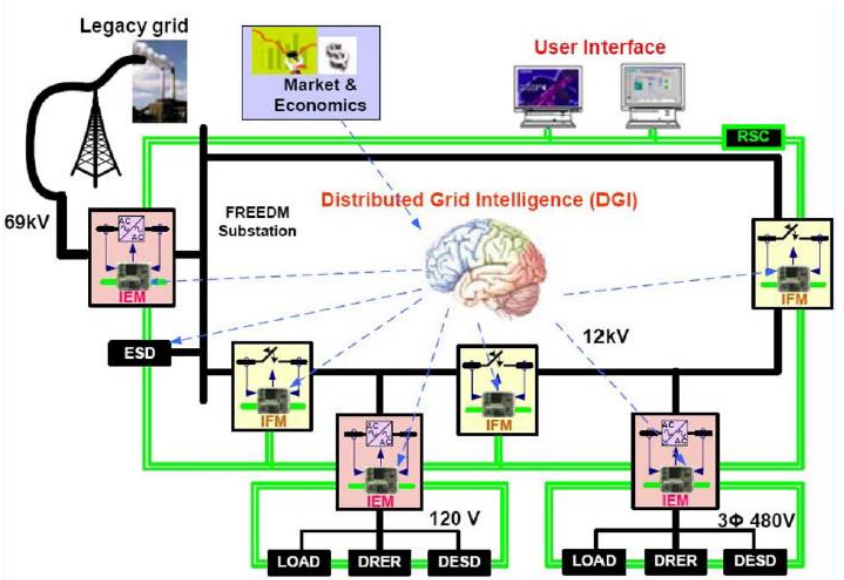
Source: 2010, Alex, IEEE Proceedings



Envisioned system based on wide-scale use of Distributed renewable energy resource and storage

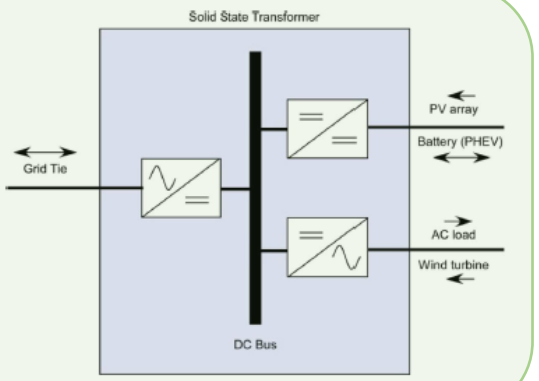


The interface of a future home in the Envisioned system



Key elements of the Envisioned system

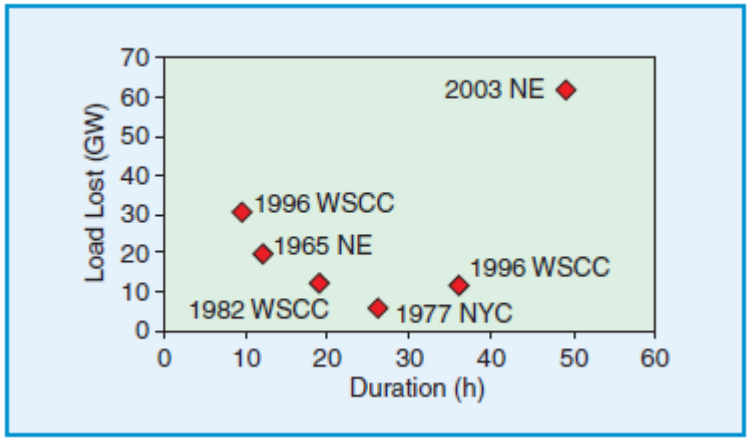
The SST typically includes a high-voltage ac to dc power conversion stage, a high-frequency DC/DC converter stage to produce a regulated DC bus, and a DC/AC stage to produce a low voltage regulated AC bus. Therefore, an SST is essentially a three-port power exchanger and energy router.



- FREEDM Future renewable electric energy delivery and management.
- DRER Distributed renewable energy resource
- DESD Distributed energy storage device.
- IEM Intelligent energy management.
- IFM Intelligent fault management.
- SST Solid state transformer.
- FID Fault isolation device.
- RSC Reliable and secure communication.
- DGI Distributed grid intelligence.

Resilience/Self-healing Capability

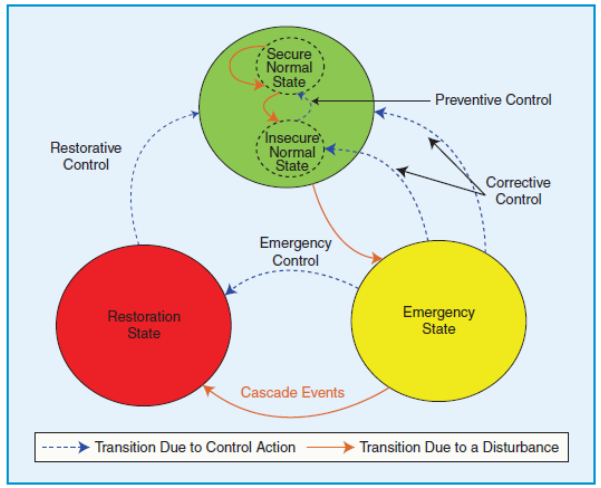
EPRI has estimated that "across all business sectors, the U.S. economy is losing between US $104 billion and US $164 billion a year to outages."



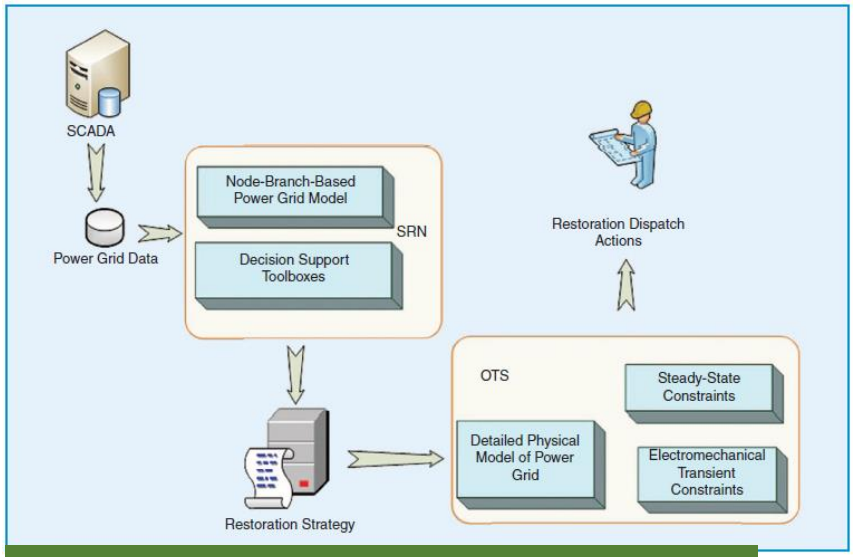
Major blackout events in the United States and their associated impacts in terms of load lost. NE = Northeast; NYC = New York City; WSCC = West Coast; MW = Midwest.

Benefits of Self healing

- **(i) Economics**
- **(ii) Security**
- **(iii) Safety**
- **(iv) Environmental**

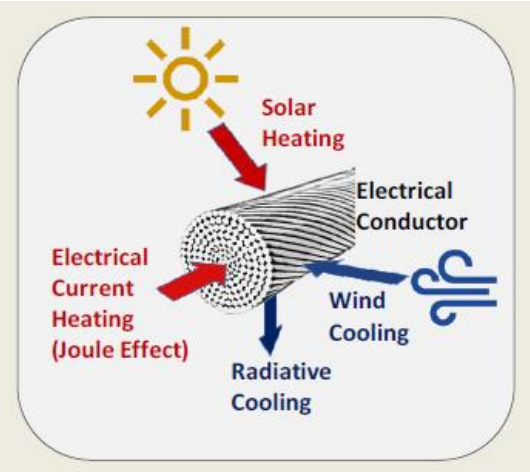


The operation states of a power system

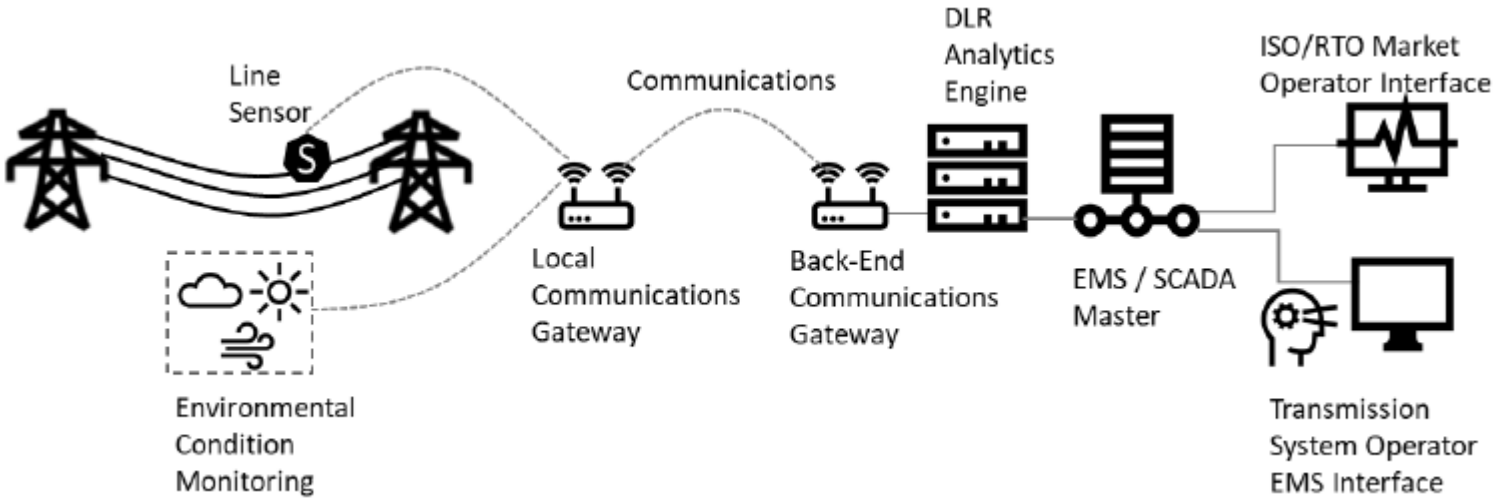


A restoration decision support system for system operators

Dynamic Line Ratings (DLR)



Factors Affecting Line Ratings



Dynamic line rating technology in transmission system operations

DLR systems help determine the real-time and forecasted current-carrying capacity

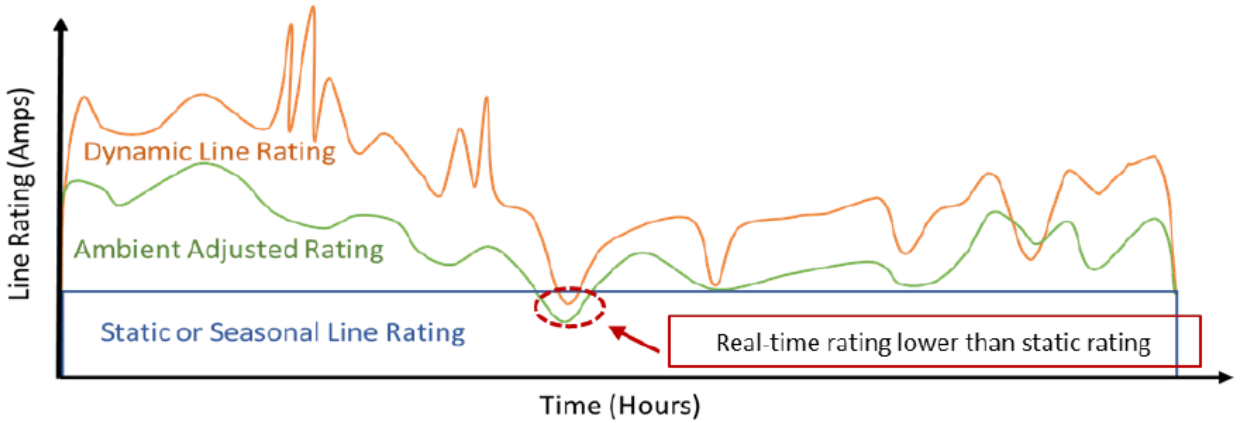
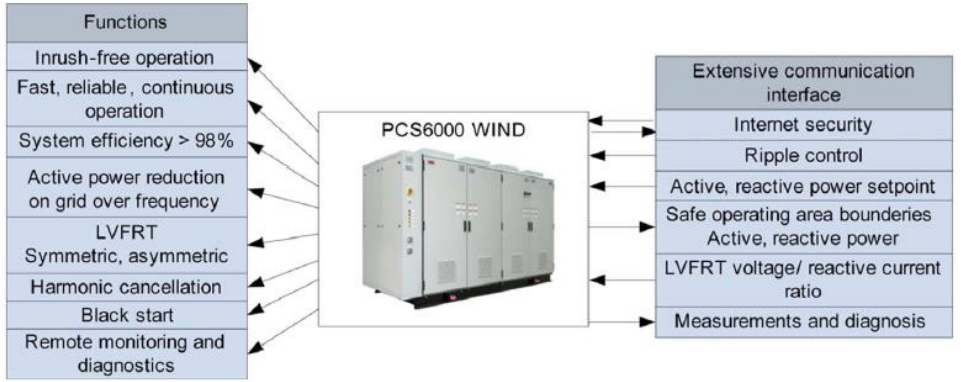


Illustration of DLR rating providing additional line capacity

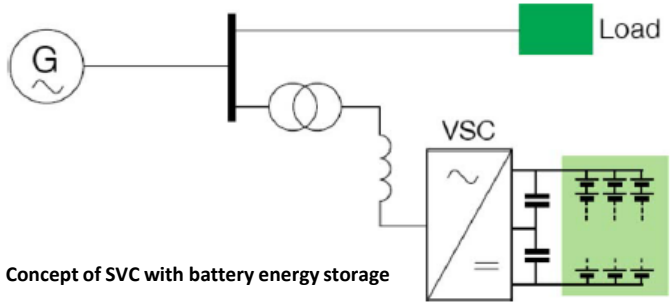
Wind Energy in Context of Smart Grid

Interconnection of large wind farms with power grid can add a new degree of control to the smart power system

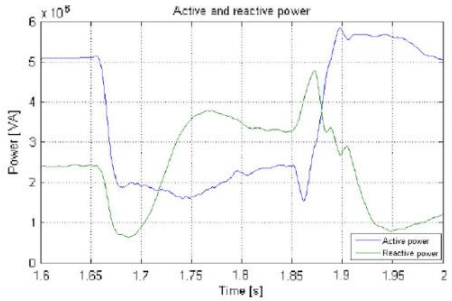
- A smart grid allow wind turbines as intermittent sources
- Advanced wind turbines with power electronics controls and other devices can support a grid with active/reactive power and protect the equipment during severe grid disturbances.



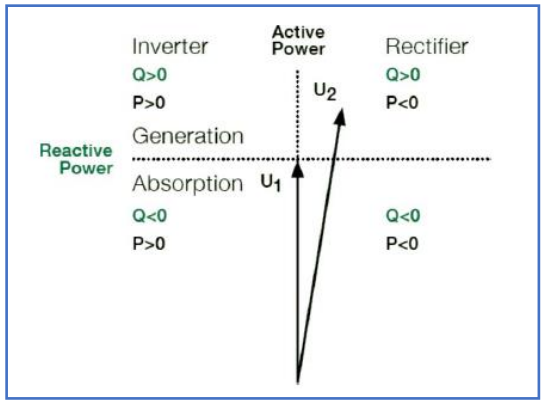
Functions of the full-scale converter for wind turbine applications relevant to Smart Grid. LVFRTV (Low Voltage Fault Ride Through).



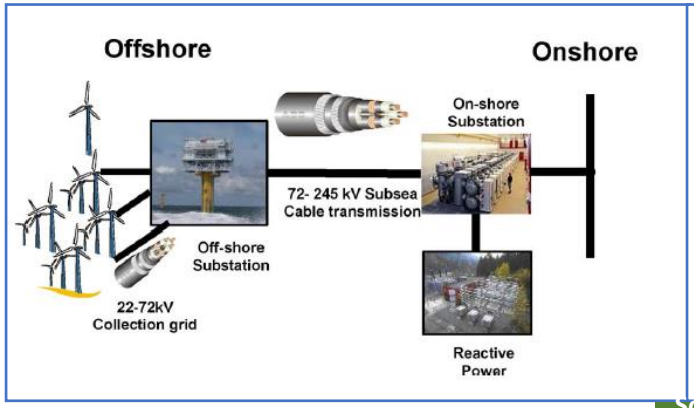
Concept of SVC with battery energy storage



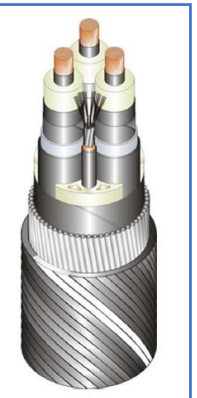
Active and reactive power output of the converter during fault.



Operational regimes of the SVC with Energy Storage. (U1-system voltage at the bus, U2-voltage at the VSC terminals)

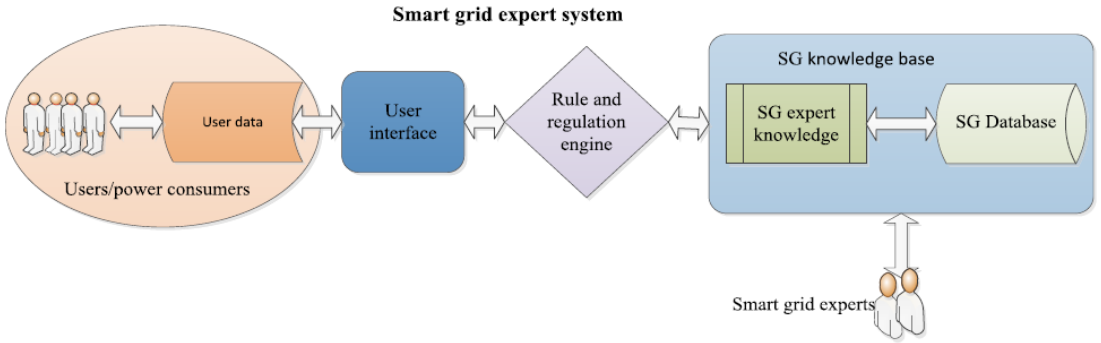


Subsea cable transmission connecting offshore wind farm with onshore power grid

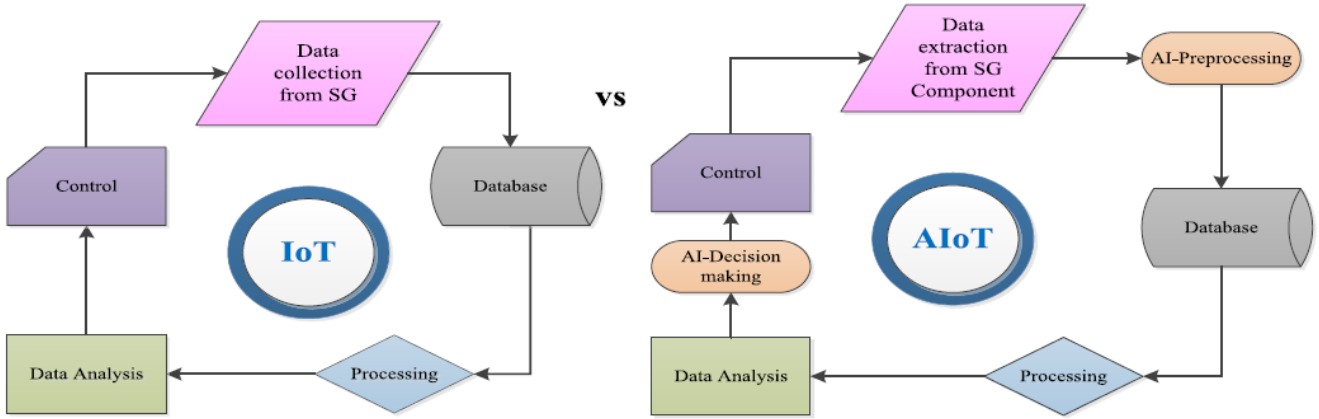


Solid dielectric submarine cable design up to 230 kV AC

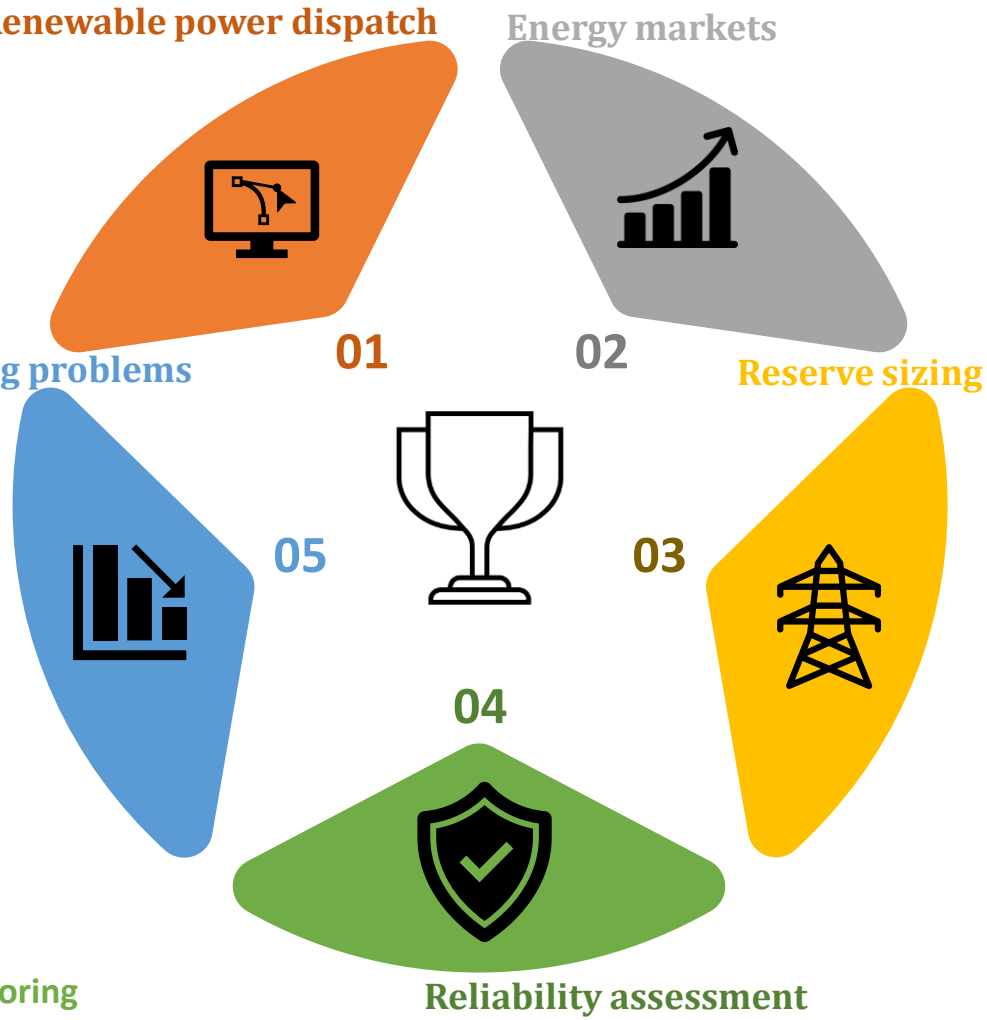
Aritificial Intelligence and Machine Learning



Expert system for smart grid

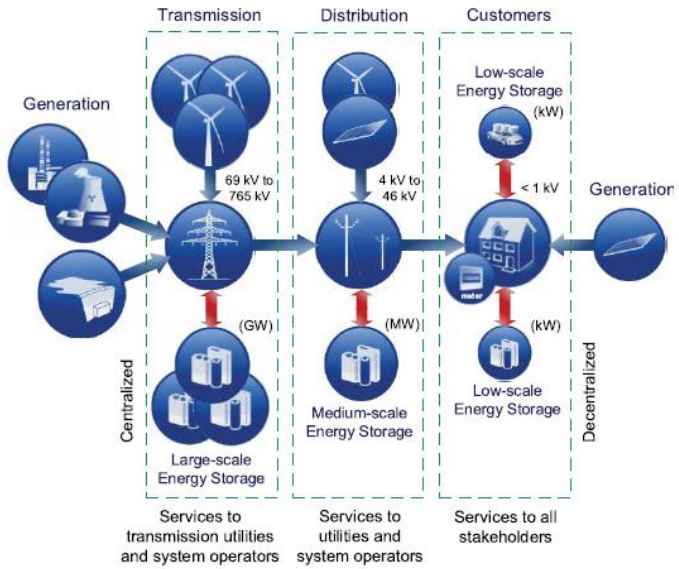


Artificial Intelligence of Things (AIoT) in smart grid

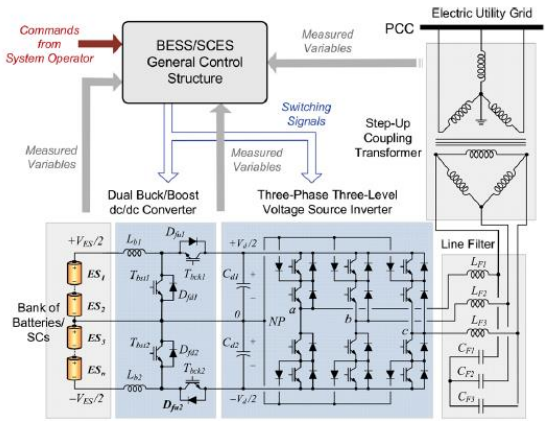


- Grid security
- Real-time faults detection and monitoring
- Load prediction
- Grid stability assessments

Control Storage in Smart Grid



Potential deployment of energy storage at different levels of the smart grid

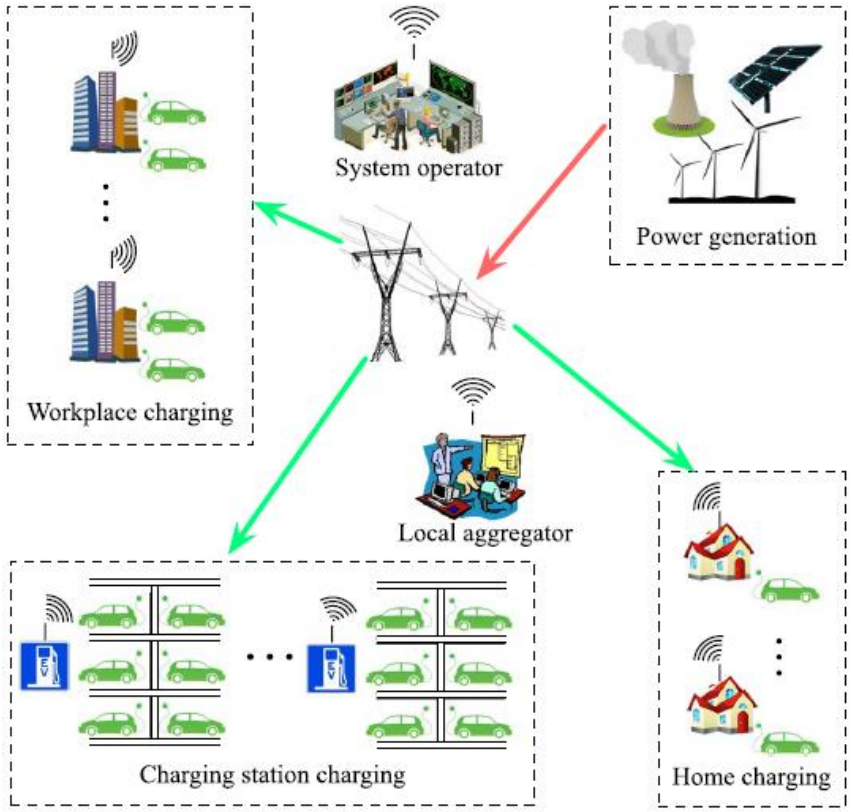


General architecture of selected distributed energy storage technologies: BESS/SCES system

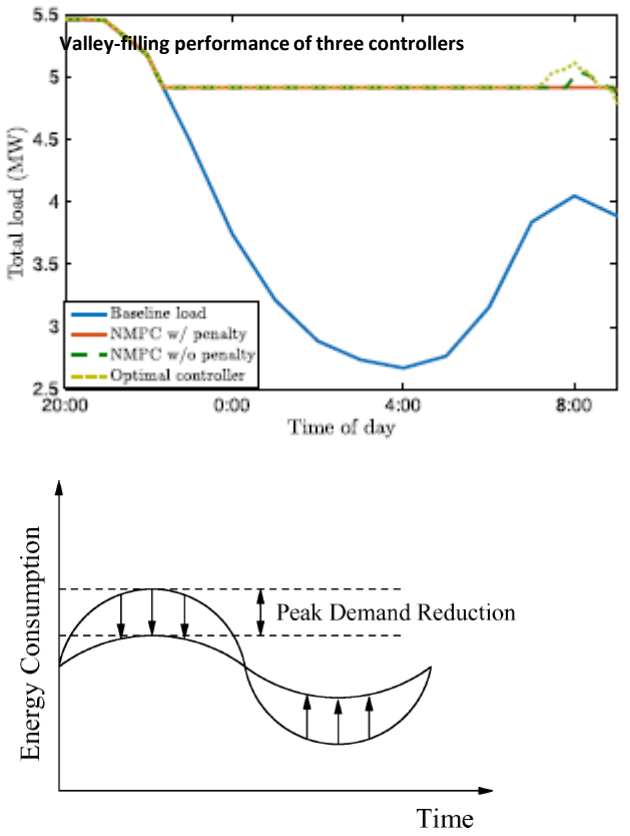
Major Services Provided by Energy Storage to Three Stakeholder

EPS Operators	Utilities	Customers
Energy arbitrage	Transmission deferral	Time-of-use bill management
Load levelling	Distribution deferral	Demand charge reduction
Peak shaving	Resource adequacy	Increased dispersed generation self-consumption
Non-spinning reserve	Transmission congestion relief	Backup power
Black start	Distribution congestion relief	Power quality improvement
Frequency control		
Voltage control		
Spinning reserve		
Integration of variable and intermittent RESs		
Grid resilience strengthening		

Control Electrical Vehicle in Smart Grid

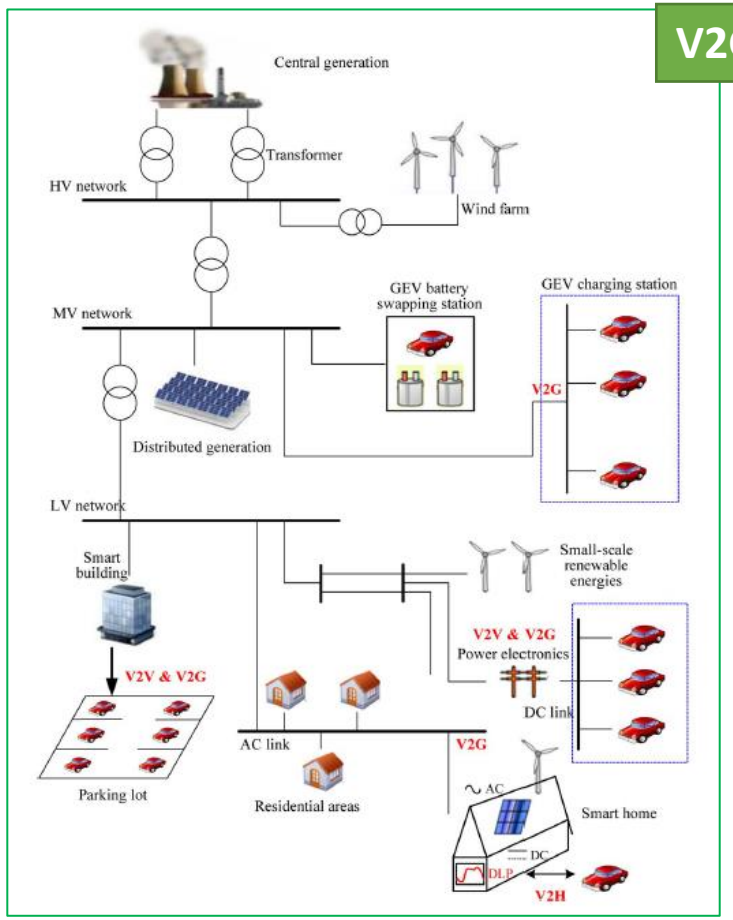


Conceptual scheme of a smart grid for controlling PHEVs' charging.



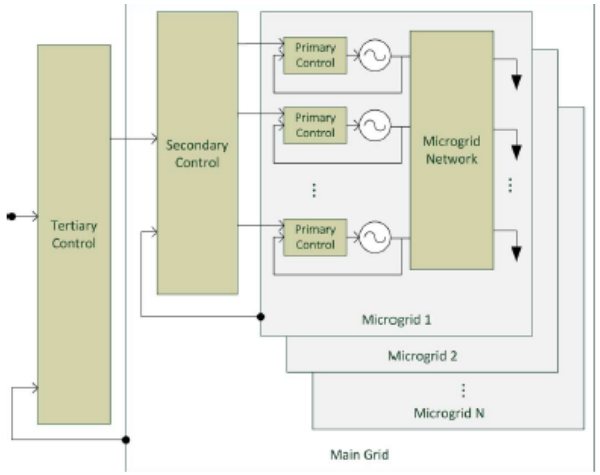
The peak demand for electricity will be reduced by the use of smart appliances, local generators, and/or local energy storage

V2G

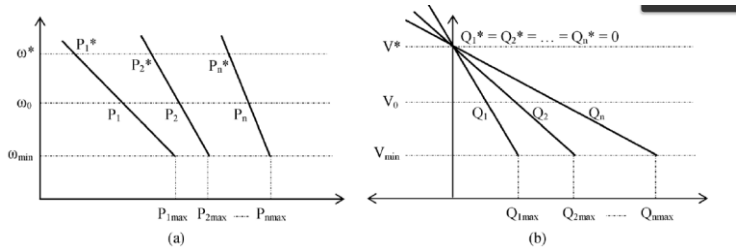


Electrical Vehicle Technology

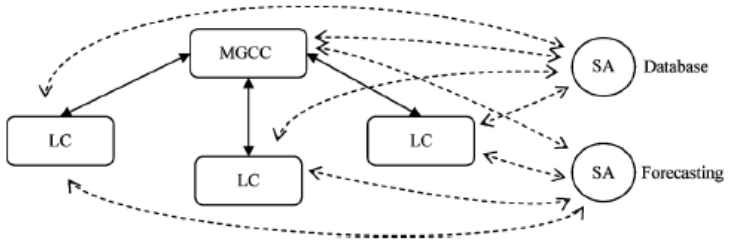
Advanced Microgrid Control



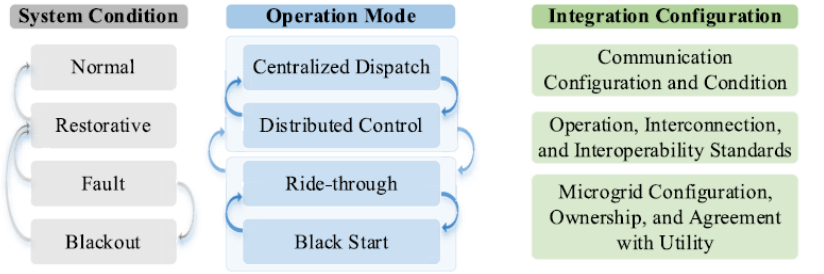
Hierarchical control levels: primary control, secondary control, and tertiary control.



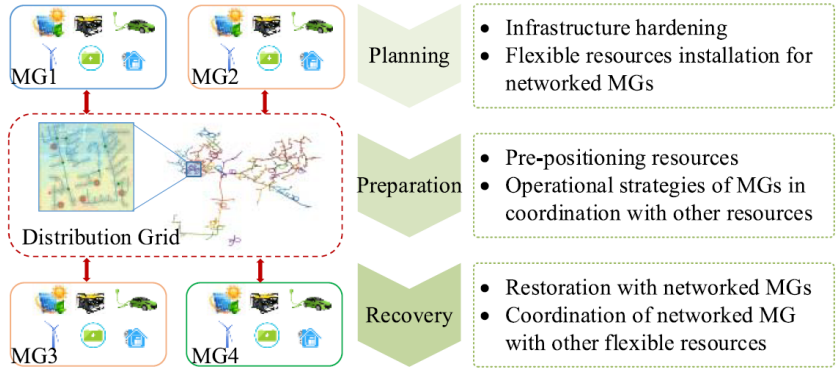
Primary control: Conventional droop characteristics (a) P-ω droop. (b) Q-V droop



Decentralized: MAS-based architecture with service agents Local Controllers (LCs); Service agents (SA).



Operation modes of Networked Microgrids

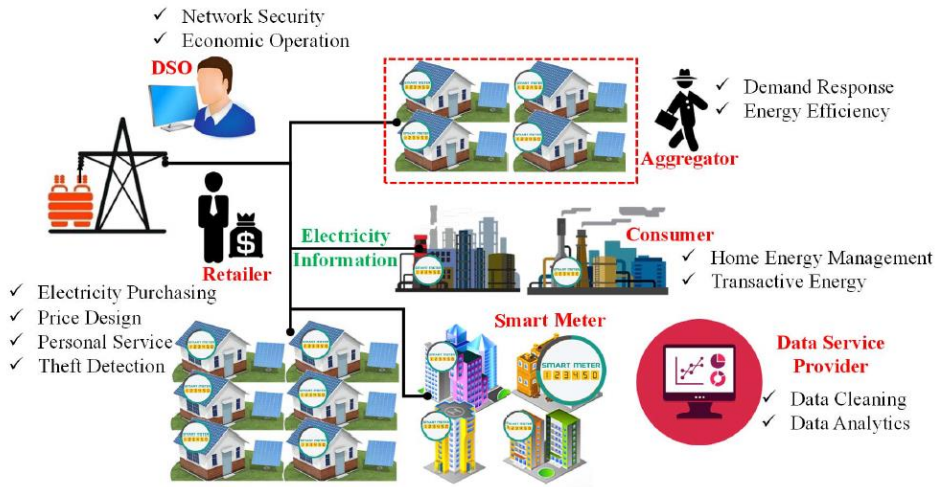


A resilience-centric paradigm based on NMGs

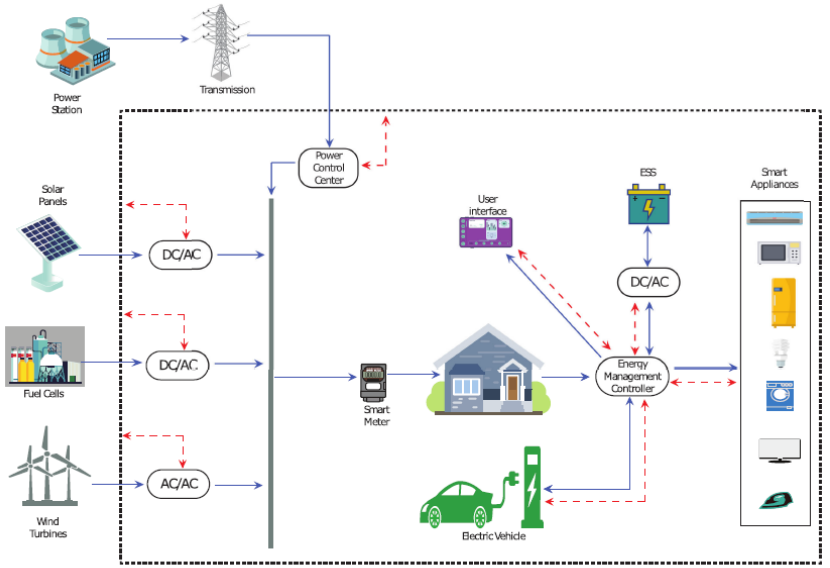
03

MARKET

Demand Side Managements

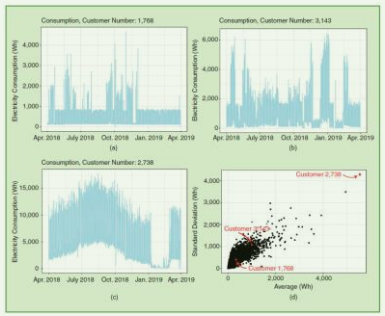


05 major players on the demand side of the power system: consumers, retailers, aggregators, distribution system operators (DSO), and data service providers.



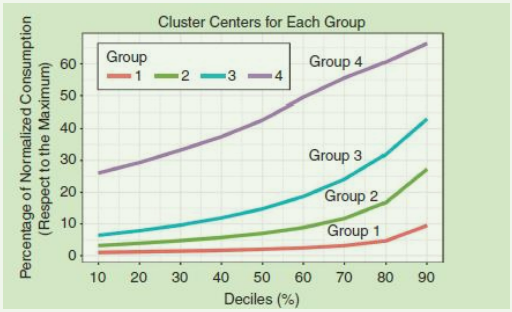
System model for demand side management

Clustering

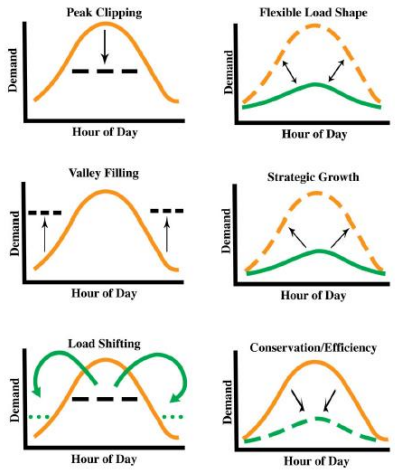


Clustering application

- Development of personalized products (e.g., electricity tariffs) in each
- implementation of demand-response programs
- perform ex-post analysis and customer diagnosis
- help to design more reliable electrical systems. adoption of new technologies, such as household solar panels, EV,Bess
- demand forecasting to make a more precise purchase in the wholesale electricity market.

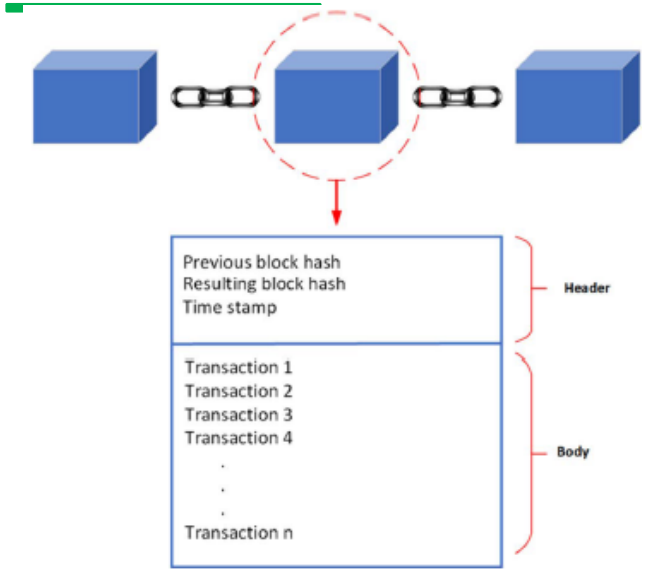


DSM

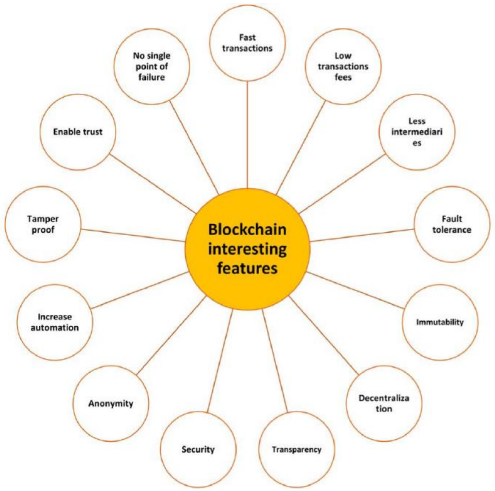


Demand side management techniques

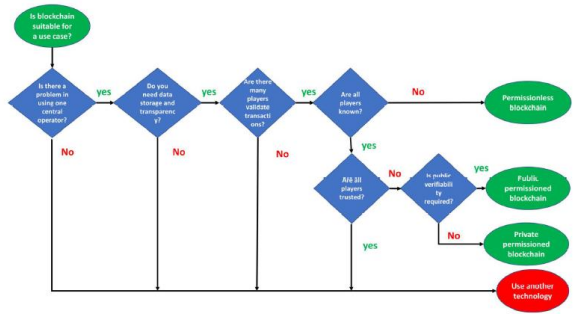
Blockchain Potential Applications in Electricity Sector



Blockchain general structure

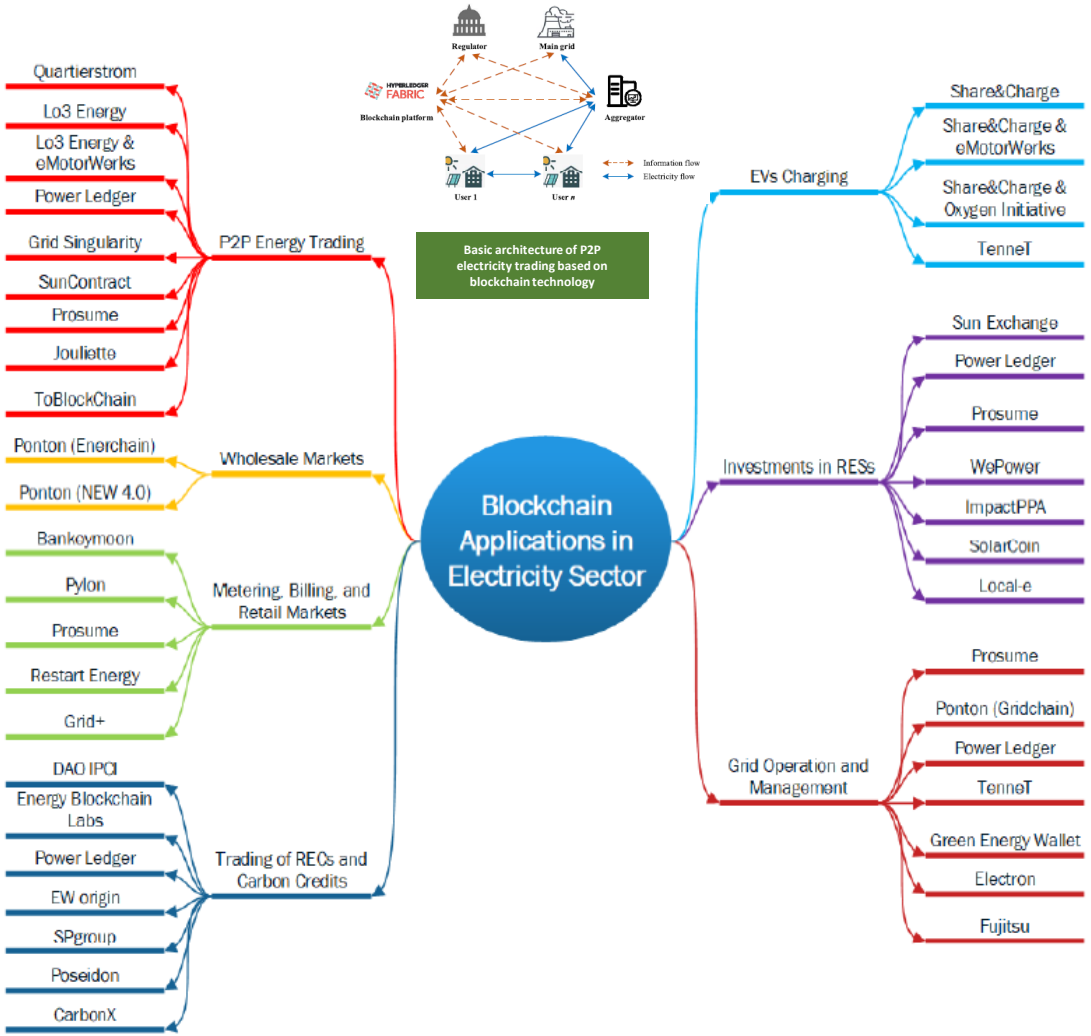


Blockchain technology main features



Preliminary evaluation criteria for suitability of blockchain technology to an application.

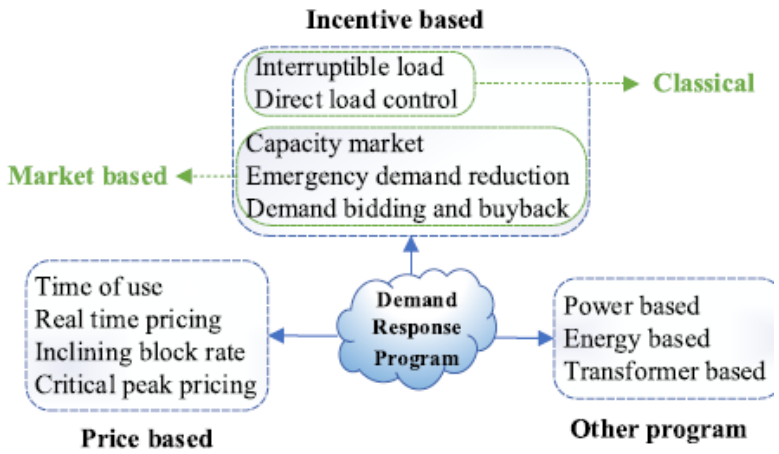
Classification of blockchain applications



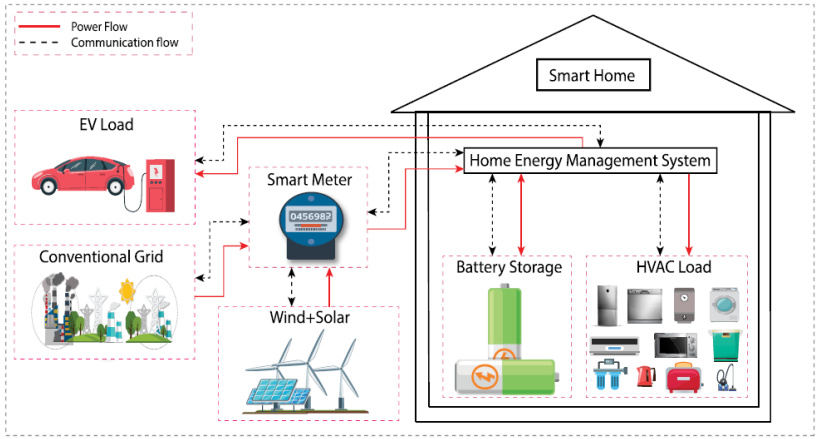
Basic architecture of P2P electricity trading based on blockchain technology

Projects and startups investigating blockchain applications in the electricity sector

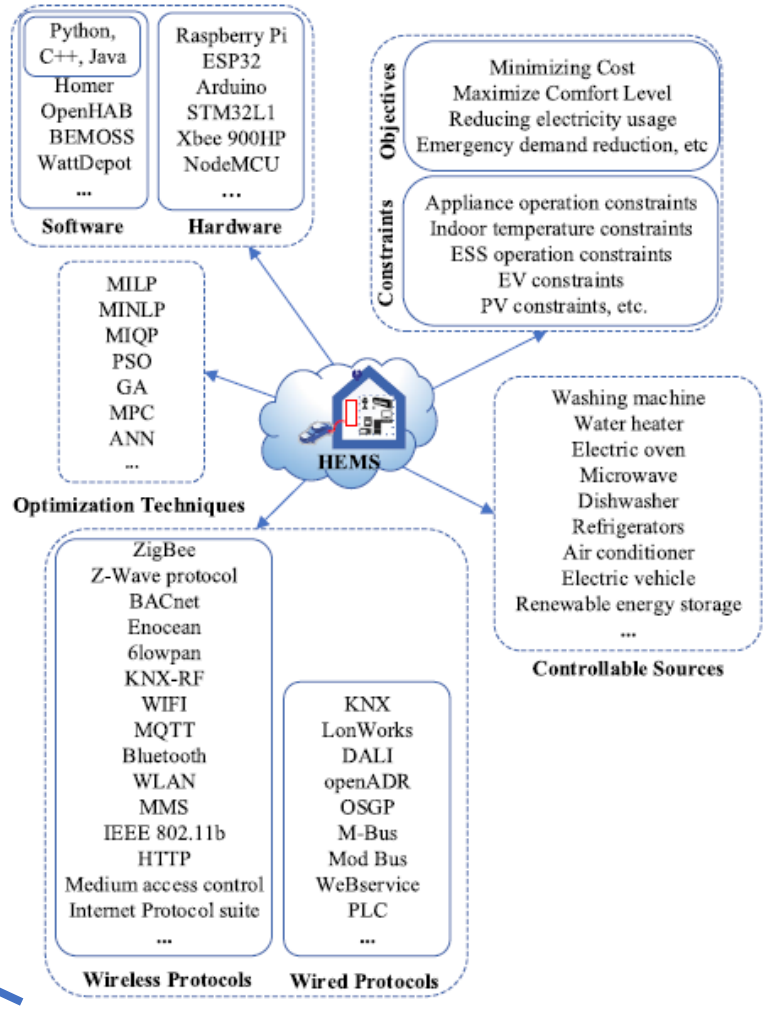
Home Management for Demand-Side Management



Demand Response Definition



Smart House Energy Management



Overview of home energy management system

Detection Methods in Smart Meters for Electricity Thefts

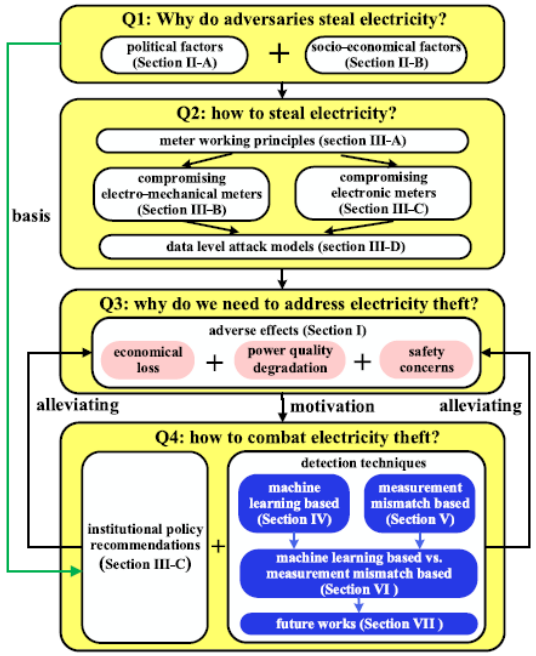
Sample Electricity Theft Statistics

Country	% power stolen	Revenue losses
USA [15]	0.5% ∼ 3.5%	$1 ∼ 10B
India [11][16]	30%	$16.2B
South Africa [17]	33%	20B Rand ($1.5B)
Netherlands [18]	23%	€114M($123.49M)
Brazil [18] [19]	20 ∼ 30%	8B reais($3.7B)
Bangladesh [15]	14%	396B TK($50.86M)
Malaysia [20]	20%	$229M
Turkish[21]	15%	$1B
Jamaica[22]	18%	$46M
Canada [23]	–	100M CAD

Laws Relevant to Electricity Theft

Countries	Laws	Punishment
UK	Theft Act 1968	Imprisonment not exceeding five years [40]
India	The Electricity Act 2003	Imprisonment from six months to five years; or/and fine not less than three times the financial gain by electricity theft [41]
China	Electricity Law	A fine of up to five times the amount of the electricity fees that should be paid or prosecuted for criminal liability
Pakistan	Pakistan Penal Code Electricity Theft Amendment 2016	Imprisonment up to three years or/and with fines up to ten million rupees [42]
Turkey	Criminal Code	Imprisonment from 1 to 5 years [43]
Algeria	Code Penal Art. 350	Imprisonment from 1 to 5 years and fines from 500 to 20,000 dinars [44]
Nigeria	Nigerian Electricity Regulatory Commission	Fines from N50,000 to N200,000 [45]

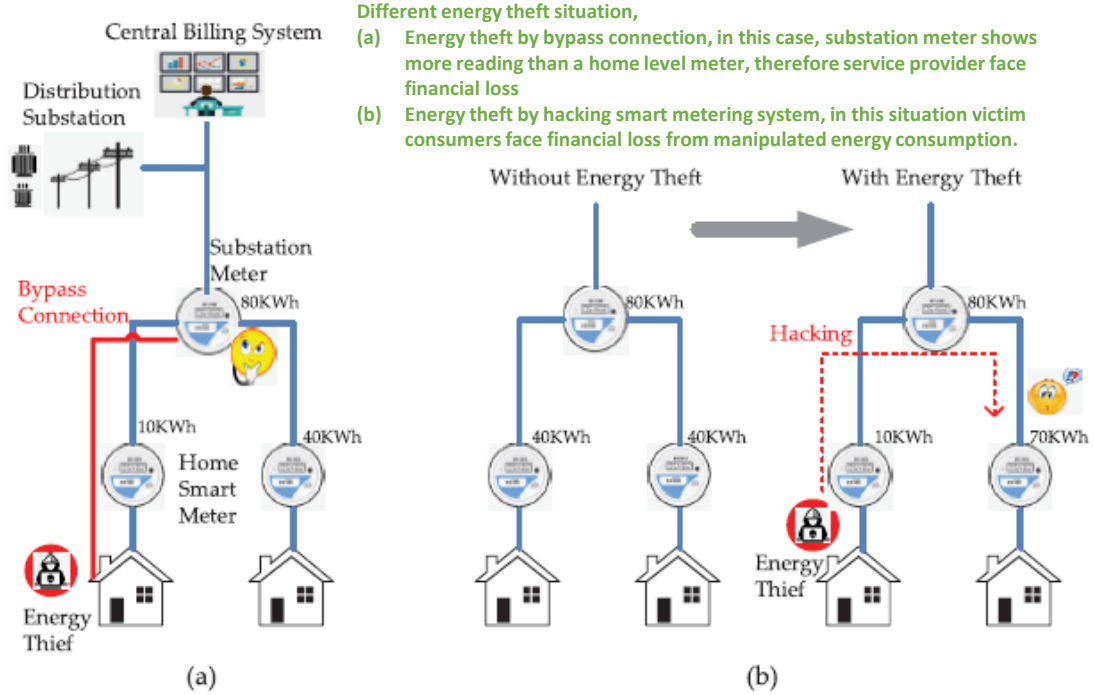
Problem statement

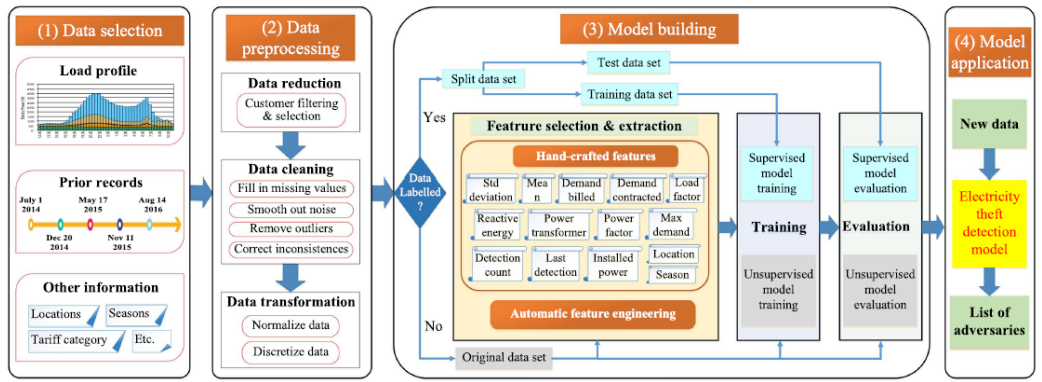


Different energy theft situation,

(a) Energy theft by bypass connection, in this case, substation meter shows more reading than a home level meter, therefore service provider face financial loss

(b) Energy theft by hacking smart metering system, in this situation victim consumers face financial loss from manipulated energy consumption.

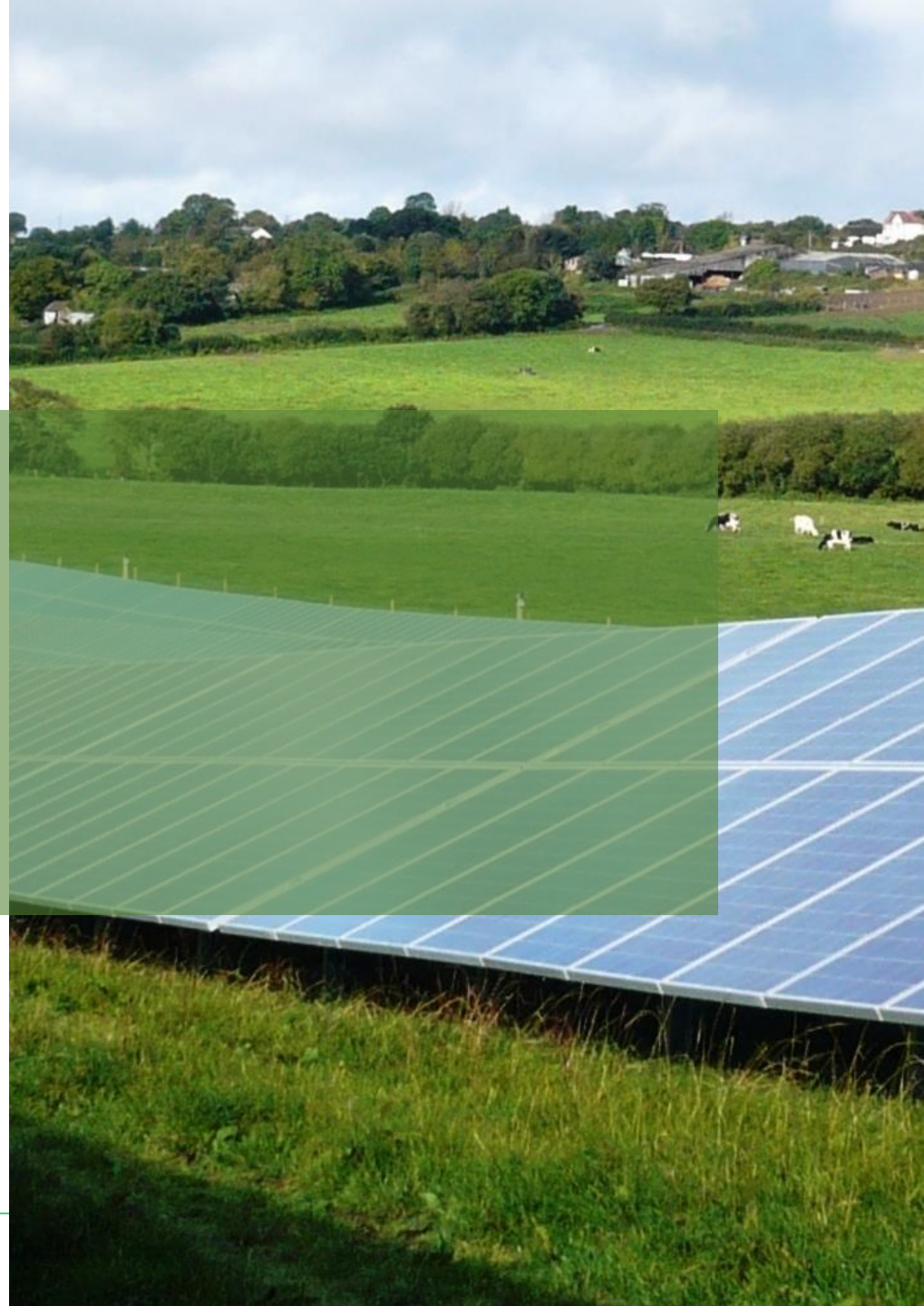




Common work-flow of machine learning-based detection methods

Outline

1. Smart Grid Perspective
2. Vietnam Smart Grid Fact
3. Smart Grid Research Topic Trend
4. **Discussion and Recommendation**
5. Conclusion



Demonstration and Policy Directions for Smart Grid

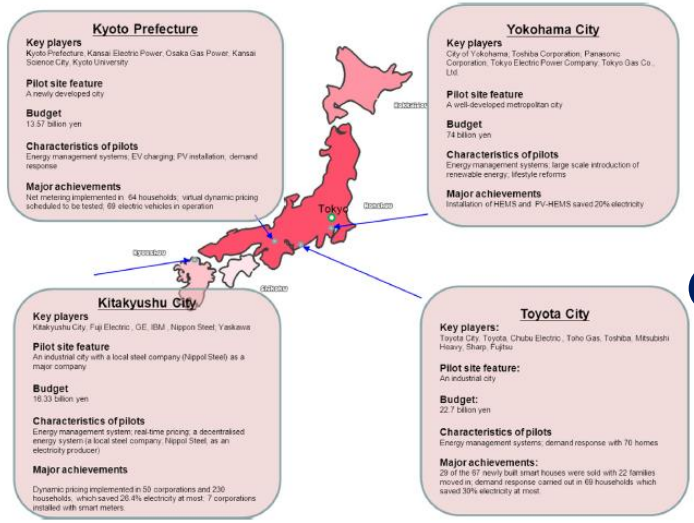
The Jeju smart grid test bed in Korea

Features:

— Integrated Test Bed
— Close Collaboration Between Public and Private Sectors
— Verification of Different Power Market Models
• Participants: Korea Electric Power Corporation(KEPCO) Plus Automakers, Telecommunications Companies and Home Appliance Manufacturers
-Includes Major Companies Such as LG, SKT, KT, and Samsung
• Open to Foreign Companies

Grid4EU demonstration sites

4.950,1 Billion VND for Con Dao Grid-connected Power Cables

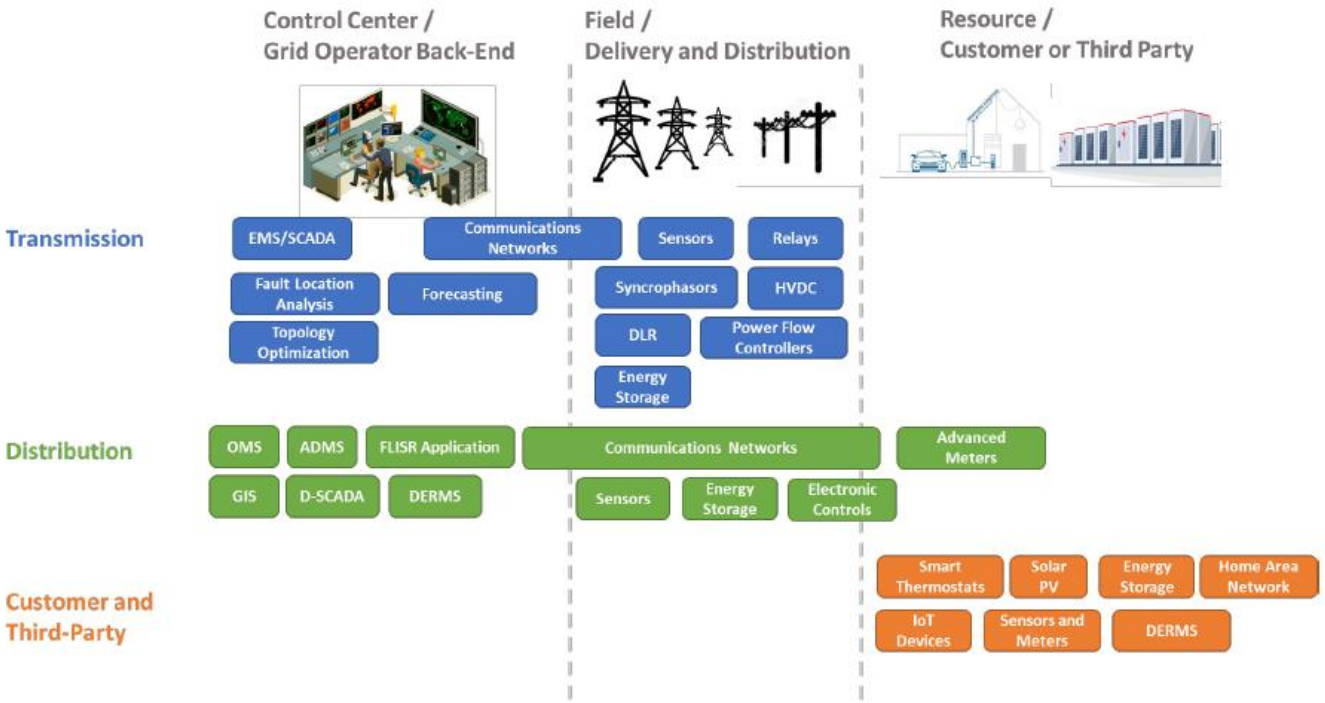


04 large-scale smart-community demonstration projects in Japan

A number of key steps should be taken to ensure a successful large-scale demonstration.

1. Engaging stakeholders, from the beginning of the demonstration (defining its scale, scope, and objectives) to the end (when results are evaluated, and next steps are discussed):
2. Linking the scale, scope, and objectives of the demonstration to the information needed to commit resources to building a smart grid
3. Defining metrics for evaluating demonstration results
4. Coordinating the planning of the demonstration with other demonstration projects
5. Using scientific study methodologies rather than just technology demonstrations, as appropriate

Driving Force of Smart Grid

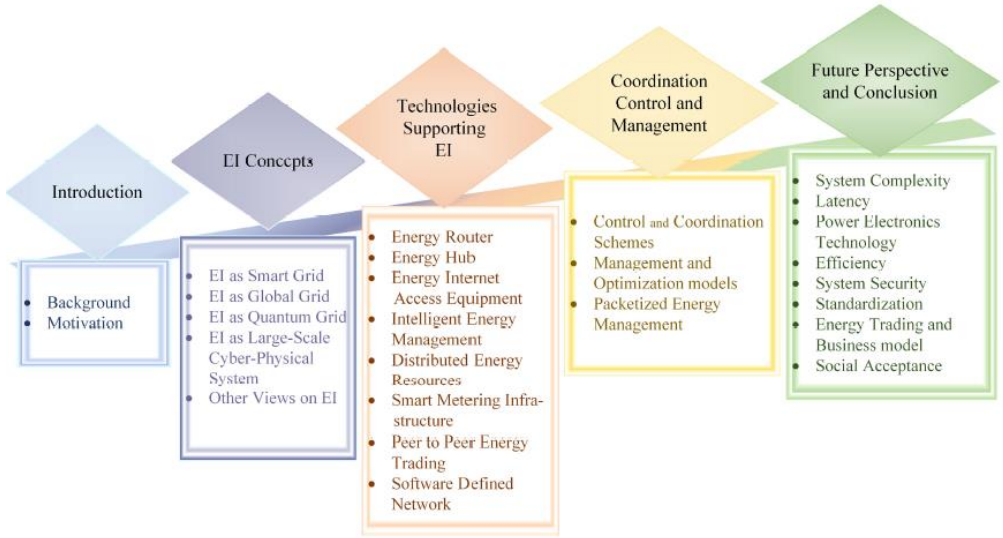


TECHNOLOGIES AND RESOURCES ACROSS TRANSMISSION, DISTRIBUTION, AND CUSTOMER SYSTEMS

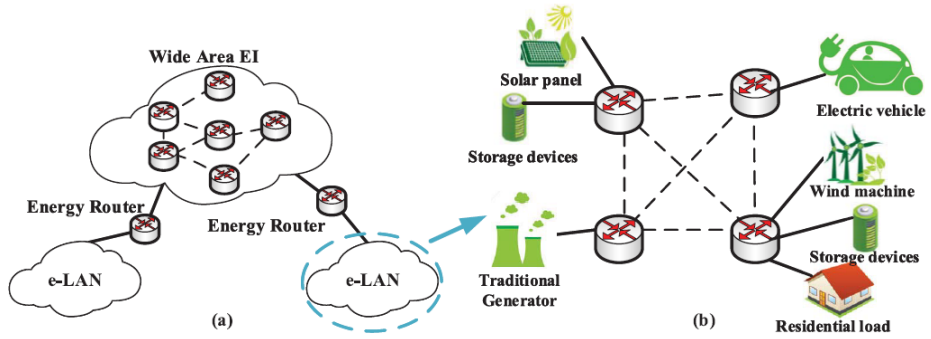
The five forces are collectively driving grid transformation:

1. The advancement of technology
2. State, and local policies
3. The emergence of new participants
4. The convergence of the electric grid with other systems
5. Increasing concerns regarding the security and resilience

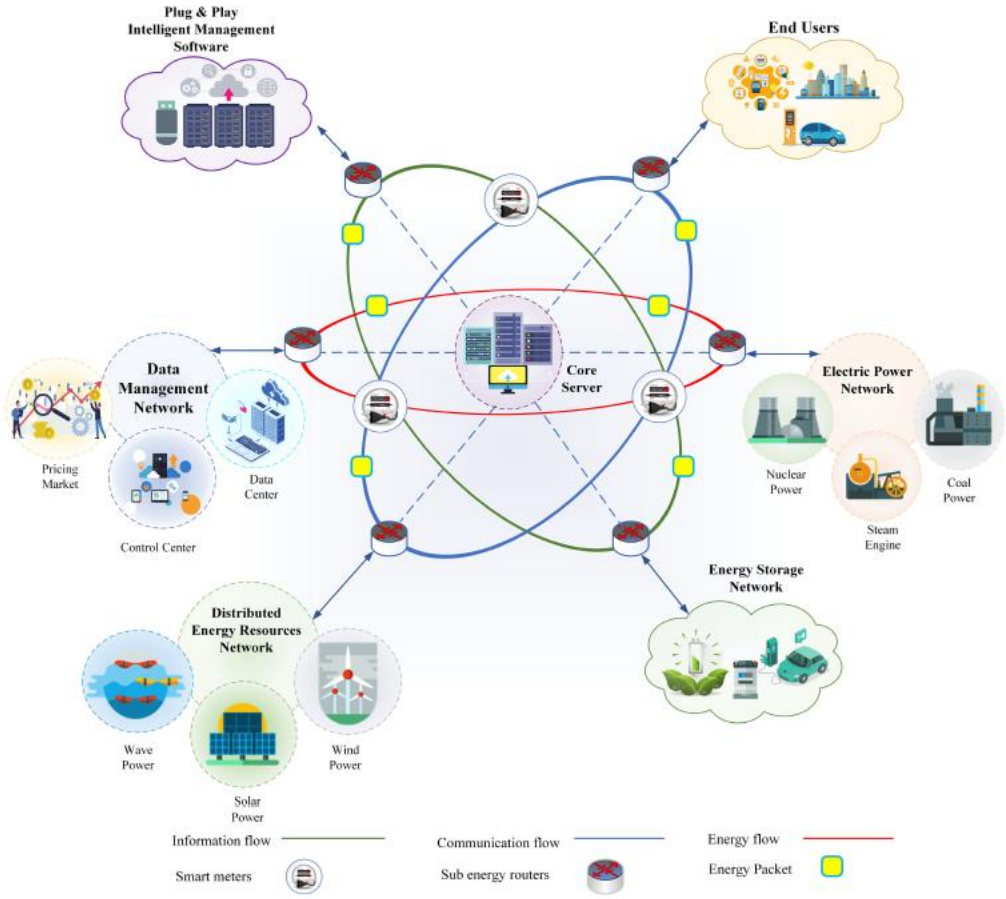
Energy Internet (EI) ~ A truly Intelligent Grid



Overview of the EI structure and the technological challenges



(a) An example wide area EI. (b) An example e-LAN.

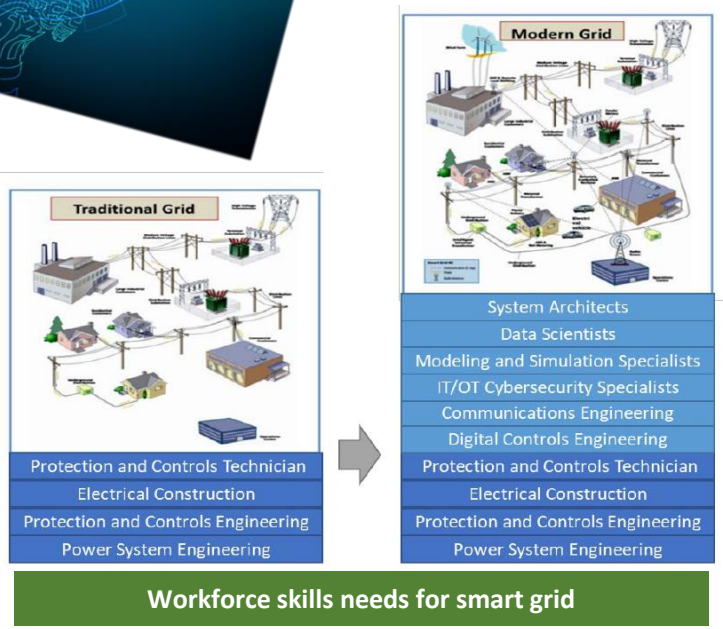


Basic structure of an EI comprising multiple networks, such as a distributive energy resources network, energy storage network, data management network, and internet and communication networks with features, like Plug and play, intelligent soft ware, sub energy routers, and smart meters.

Recommendations for Future Vietnam Smart Grid

- Implementing advanced smart grid infrastructure
- Enhance legal framework for smart grid technology and investment
- Update the world's technology

- Well-Prepared Workforces
- Demonstration Projects



Workforce skills needs for smart grid

CONCLUDING REMARKS

1. Smart Grid Perspective
2. Smart Grid in Vietnam
3. Smart Grid State-of-the-art Topics
4. Implications

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