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Introduction to Wide area measurement system & challenges in adaptive protection in Smart Grid

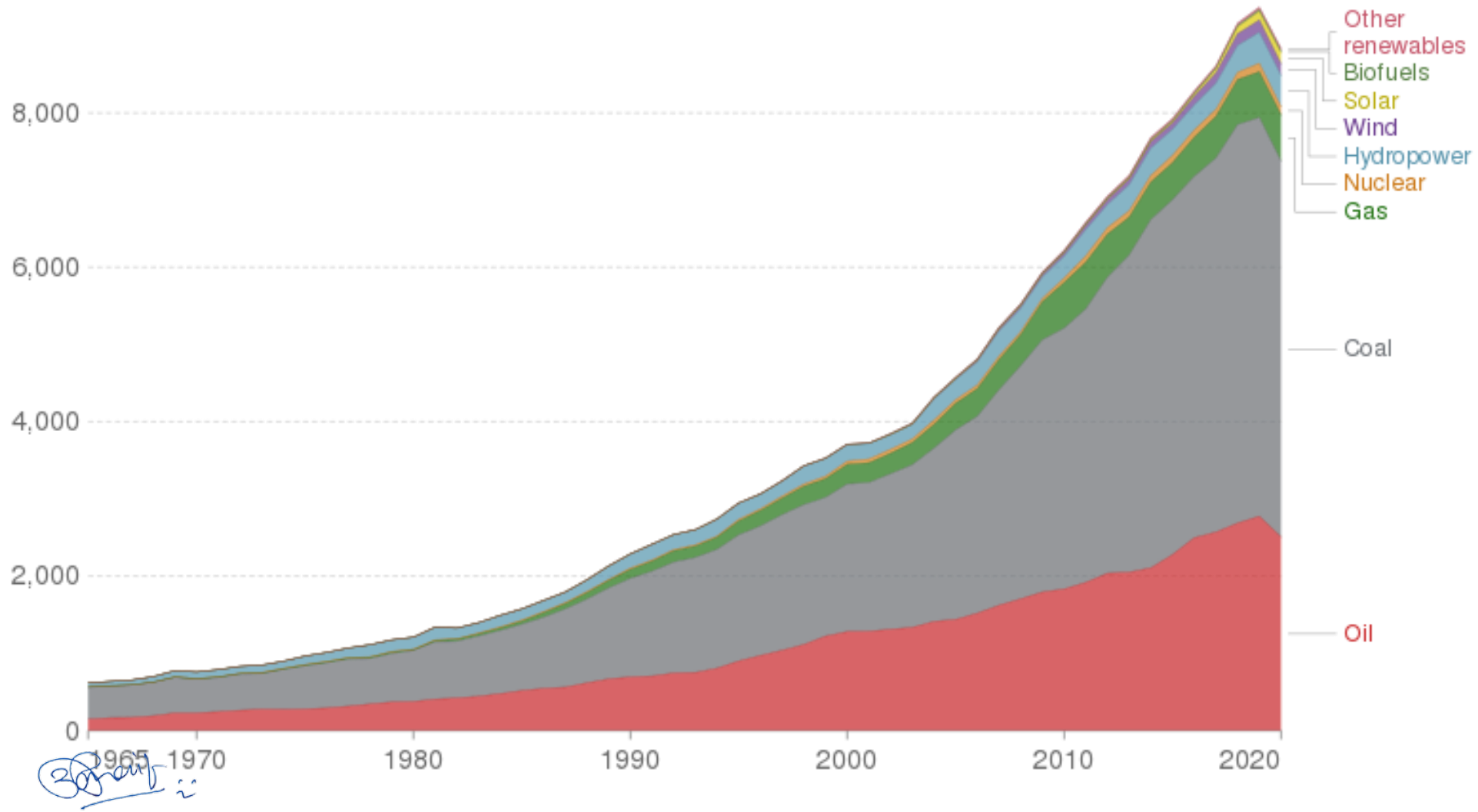
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Energy consumption by source, India

Our World in Data

Primary energy consumption is measured in terawatt-hours (TWh). Here an inefficiency factor (the 'substitution' method) has been applied for fossil fuels, meaning the shares by each energy source give a better approximation of final energy consumption.



Source: BP Statistical Review of World Energy
Note: 'Other renewables' includes geothermal, biomass and waste energy.

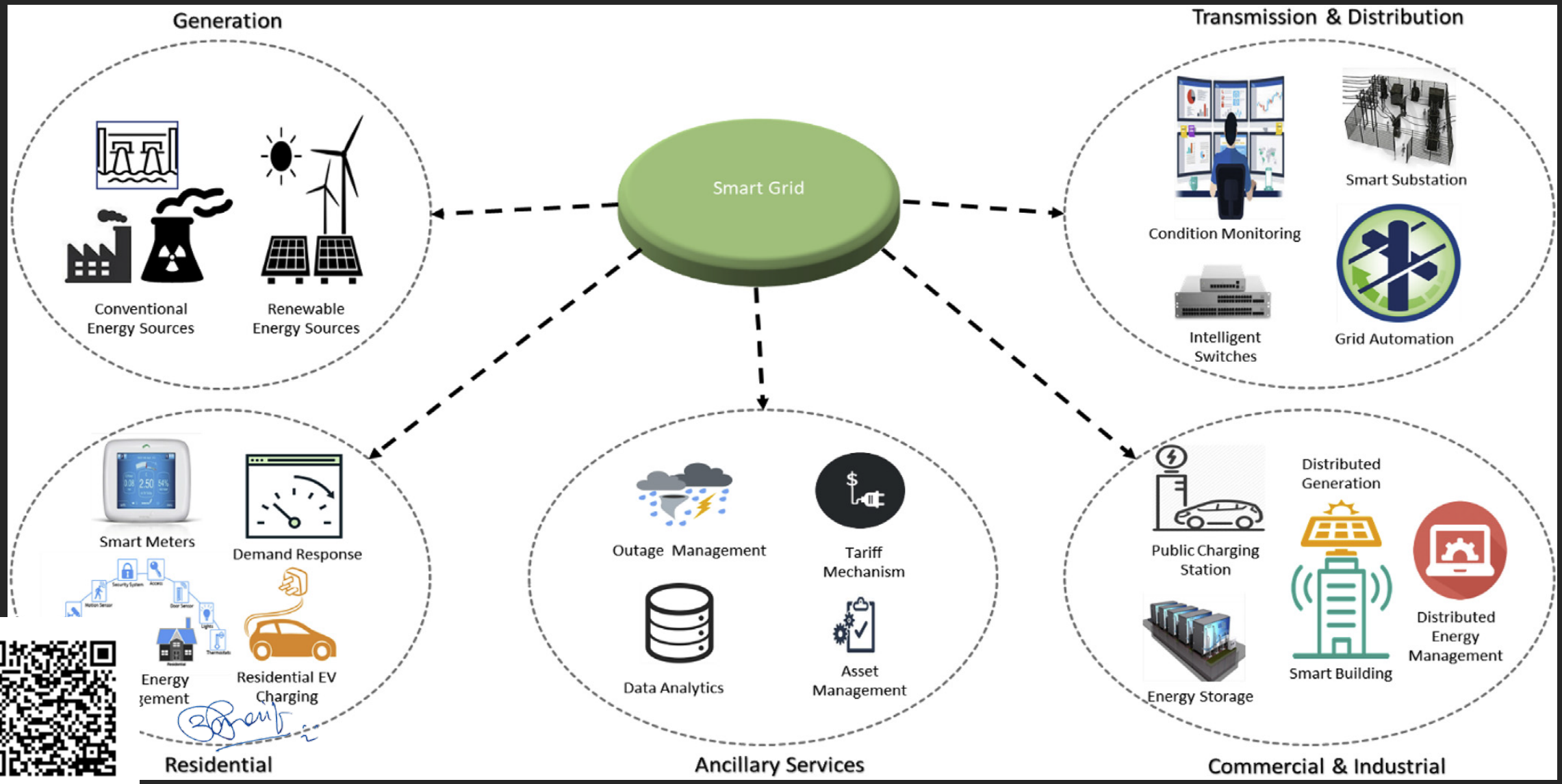
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Source	Installed Capacity (MW)	% of Share in Total
Conventional Power Sources	**237,269**	**57.7%**
Coal	205,235	49.3%
Lignite	6,620	1.6%
Gas	24,824	6.0%
Diesel	589	0.1%
Renewable Energy Sources	**178,790 (MW)**	43%
Hydro	46,850	11.3%
Wind	42,633	10.2%
Solar	66,780	16.1%
Bio Mass Power/Cogen	10,248	2.5%
Waste to Energy	554	0.1%
ydro	4,944	1.2%
	6,780	1.6%
tal Installed Capacity	***416,059 (MW)***	***100%***

Source: CEA & Wikipedia

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Introduction to Smart Grid



Source: Resource Policy, Elsevier

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Characteristic wise comparison of smart grid with existing grid.

	Existing grid	Smart grid
Nature of components (e.g., relay, circuit breakers)	Electromechanical	Digital
Electricity generation	Centralized system	Integration of Distributed Energy Resources into Centralized generation
Tolerance toward faults	Fault intolerant	Fault tolerant
Restoration process	Manual	Automatic (self-healing)
Outages	Prone to failures and blackouts	Adaptive and islanding facility
Tariff and Pricing	Fixed	Dynamic
Energy storing	Demand based production	Energy storage system
Transparency	Less	High
Consumer choices	Few	Increased choices
Communication between utility and consumer	Unilateral (from utility to consumer)	Bilateral
Security	Limited	Substantial
Emission of GHGs	High amount of emissions	Reduced emissions
Sensing and Monitoring	Few sensors present and manual monitoring	Large no of sensors and self-monitoring
Structure	Hierarchical and rigid	Networked and adaptive/scalable
Transmission efficiency	Less efficient	Highly efficient
Enabling of new services and market	Limited wholesale market and services	Mature, well-integrated market and support for new services (V2G, DSM etc.)
Demand response	No consumer participation and load following demand response	Adequate consumer participation and use of load shaping strategy of demand response
Power Quality	Slow response to power quality issues as focus is on outages	Power quality is a priority with rapid resolution of issues
s disturbance	Responds after fault to prevent further damage to assets	Automatically detect faults and responds to prevent/minimize the impact
nt	Little integration of operational data with asset management	Greater acquisition and integration of operational data with asset management

Source: Resource Policy, Elsevier

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Aspects of Smart Grid

- Generation
  - Renewables & Microgrid (MG)
  - Conventional sources like Thermal power plants, Gas power plants etc
- Transmission & Distribution
  - Integration of Renewable Energy sources/Distributed Energy Resources (DER)
  - Advanced Metering Infrastructure (AMI)
  - Outage Management System (OMS)
  - Peak Load Management (PLM)
  - Power Quality Management (PQM)
  - Electric Vehicles- V2G
  - Wide Area Measurement Systems (WAMS)

Energy Storage

Demand Response

Ancillary services – Data Collection, Analysis, Tariff Mechanisms, Asset Management

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Smart Grid Initiative in India

- Smart City Mission (July 2015)
  - Smart Cities Mission for developing 100 Smart Cities
  - ATAL Mission for Rejuvenation and Urban Transformation (AMRUT) for rejuvenation of 500 towns across India

- The assets and smart infrastructure created under various schemes of Govt. of India are listed as follows:
  - Geographic Information System (GIS) Mapping of the Cities
  - Billing and Customer Relationship Management Systems
  - SCADA/DMS System
  - Common Command and Control Centre
  - Outage Management Systems and Mobile Workforce Management (MWFM)
  - IT Network, Data Centre and Disaster Recovery Centre (Pillai and Sawant, 2016).

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- R-APDRP (Restructured Accelerated Power Development & Reforms Program) (2008)
- IPDS (Integrated Power Development Scheme) (2015)
- UDAY (Ujjwal Discoms Assurance Yojana) (2015)
- DDUGJY (Deen Dayal Upadhyaya Gram Jyoti Yojana) (2015)
- NSGM (National Smart Grid Mission) (2013)
- ISGF (India Smart Grid Forum) (2010)
- ISGTF (India Smart Grid Task Force) (2013)
- EESL (Energy Efficiency Services Limited) (2015)

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Pilot Projects of Smart Grid In India

- UPES, Dehradun - Integrated Distribution Automation System (MIDAS) for remote health monitoring of equipments and detection of fault location on 11 kV network

- CESC, Kota & Bharatpur - Silver Spring's standards-based IPv6 platform with two way connectivity to improves working efficiency and develops business processes and workflows which improve billing accuracy and reduce loss in energy

- Smart Grid Lab, TPDDL, Delhi - Testing and operationalizing the implementation of advanced technologies before the deployment in the field

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- IPCL, Gaya - implement smart grid technologies at its Gaya distribution Franchise (200 MVA) in the state of Bihar

- TPDDL-IBM, Delhi - successfully implemented a large-scale AMI and ADR project which connects 165 commercial and industrial consumers with load above 100 kW.

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Ministry of power smart grid pilot projects.

Sr. No.	Name of the Utility	Location	Total Project Cost (Rs. Cr.)	GoI support (Rs. Cr.)	Consu-mer base	Present status
1	APDCL, Assam	Paltan Bazar, Narengi, Ulubari - Assam	29.94	14.97	15,083	Project declared go-live on 2 May 2019 with AMI
2	CED, Chandigarh	Chandigarh	28.58	8.6	29,433	MDM System under configuration. Data centre works awarded, rest under tendering.
3	CESC, Karnataka	Mysore - Karnataka	32.59	16.28	21,824	Project completed
4	HPSEB, Himachal Pradesh	Kala Amb Industrial Area - Himachal Pradesh	19.45	9.73	1,251	Project completed
5	IIT Kanpur Smart City	Kanpur – Uttar Pradesh	12.5	6.25	–	Project completed
6	KESCO, Kanpur	Kanpur – Uttar Pradesh	319.57	95.87	539000	Request for Proposal (RfP) under preparation.
7	MSEDCL, Amravati	Amravati – Maharashtra	90.05	27.02	148495	Project under hold. New roadmap under formulation
8	MSEDCL, Nagpur	Congress Nagar, Nagpur – Maharashtra	139.15	41.75	125000	Project under hold. New roadmap under formulation
9	PED, Puducherry	Puducherry	46.11	23.06	33,499	Project declared go-live on 28 Dec 2018. 28,910 smart meters and 490 DCUs installed.
10	PSPCL, Punjab	SAS Nagar – Punjab	10.11	5.06	2734	Failure in supplying smart meters led to cancellation of contract. New roadmap under formulation.
11	Smart Grid Knowledge Centre, Haryana	Manesar – Haryana	9.8	9.8	–	Contracts awarded for HEMS, Workstations/Training Room Hardware. Building under construction. FAT for OMS awaited. Quality evaluation for MicroGrid under process.
12	TSECL, Tripura	Agartala – Tripura	63.43	31.72	45,290	Project under commercial operation
13	TSSPDCL, Telangana	Jeedimetla Industrial Area – Telangana	41.28	20.91	11,906	Project declared go-live on 30 March 2019 with single phase meters
14	UGVCL, Gujarat	Sabarmati – Gujarat	82.70	41.35	22,230	Site survey work done. Project inaugurated on 27 Feb 2019.
15	UHBVN, Haryana	Panipat - Haryana	131.25	0	11,000	Project completed
1	Bengal	Siliguri, Darjeeling – West Bengal	7.03	3.52	5,265	Project completed

Ab

Source: Resource Policy, Elsevier

Functionality under Smart Grid projects in India

Functionalities to be Adopted in Smart Grid Pilot Projects.

Functionalities → / Pilot Projects ↓	AMI-R	AMI-I	PLM	OMS	PQ	DG	MG	DR	SCADA	Other Functionalities
APDCL, Assam	×	×	×	×	×	×				
CESC, Karnataka	×	×	×	×		×	×			
HPSEB, Himachal Pradesh		×	×	×						
IIT Kanpur Smart City	×					×			×	×
PED, Puducherry	×	×								
PSPCL, Punjab	×	×	×							
Smart Grid Knowledge Centre, Haryana	×			×		×	×			×
TSECL, Tripura	×	×	×							
TSSPDCL, Telangana	×	×	×	×	×					
UGVCL, Gujarat	×	×	×	×	×					
UHBVN, Haryana	×	×	×	×					×	
WBSEDCL, West Bengal	×	×	×							
CED, Chandigarh	×	×								×
i	×	×		×				×		
s Nagar	×	×		×				×	×	
	×	×	×			×				×

Source: Resource Policy, Elsevier

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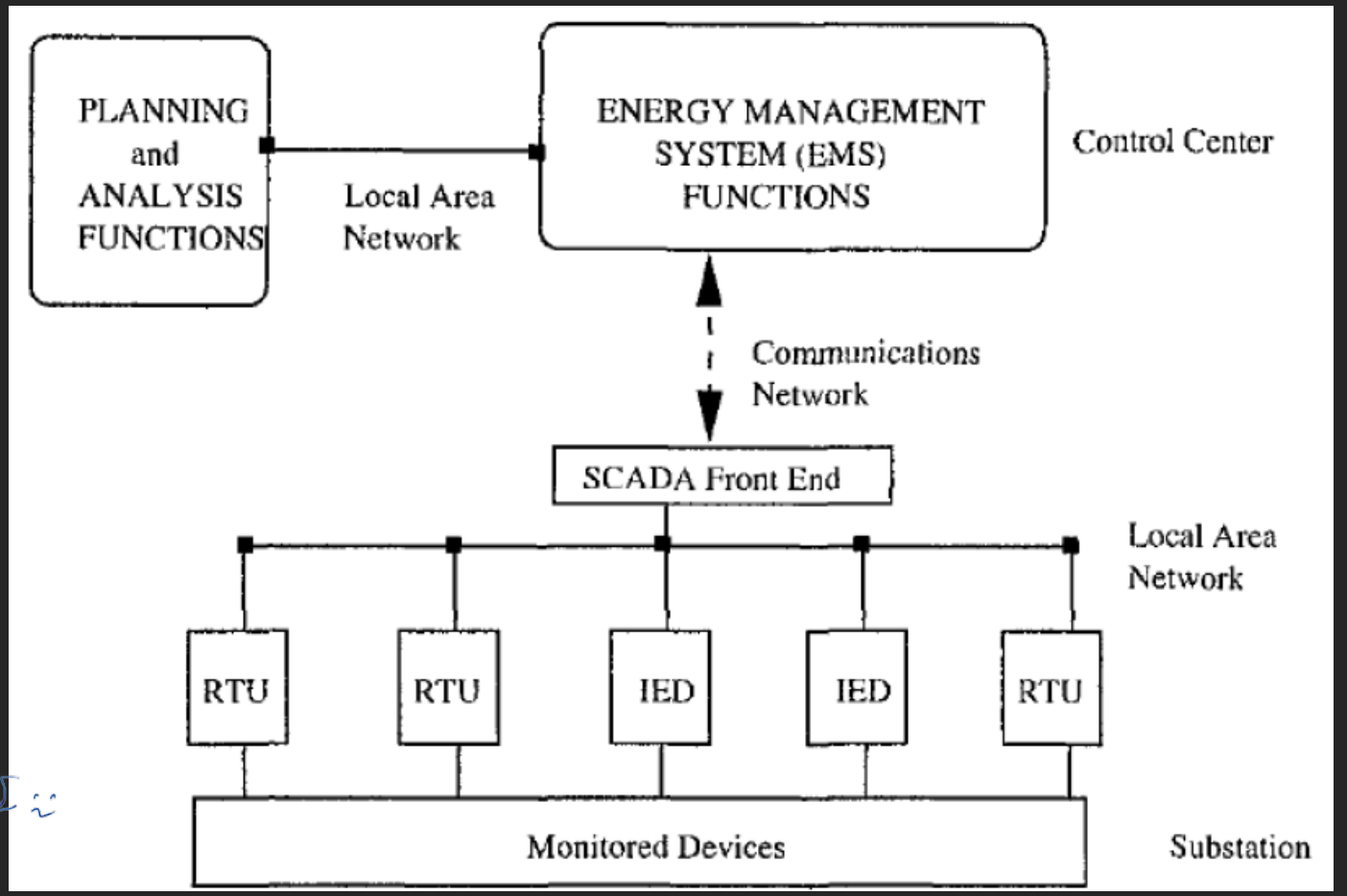
Challenges for Smart Grid

- Nationwide smart grid implementation plan lacks in commercial viability aspect.
- Lack of coordination between stakeholders for smart grid deployment
- Poor financial condition of state owned power companies
- Non-driven efforts by state owned T&D companies to upgrade power delivery infrastructure
- Inadequate skill and knowledge of personnel to operate new devices, new systems, new communication technologies
- Due to non-maturity of technologies involved in smart grid, significant capital costs
- of public awareness and consumer knowledge programs

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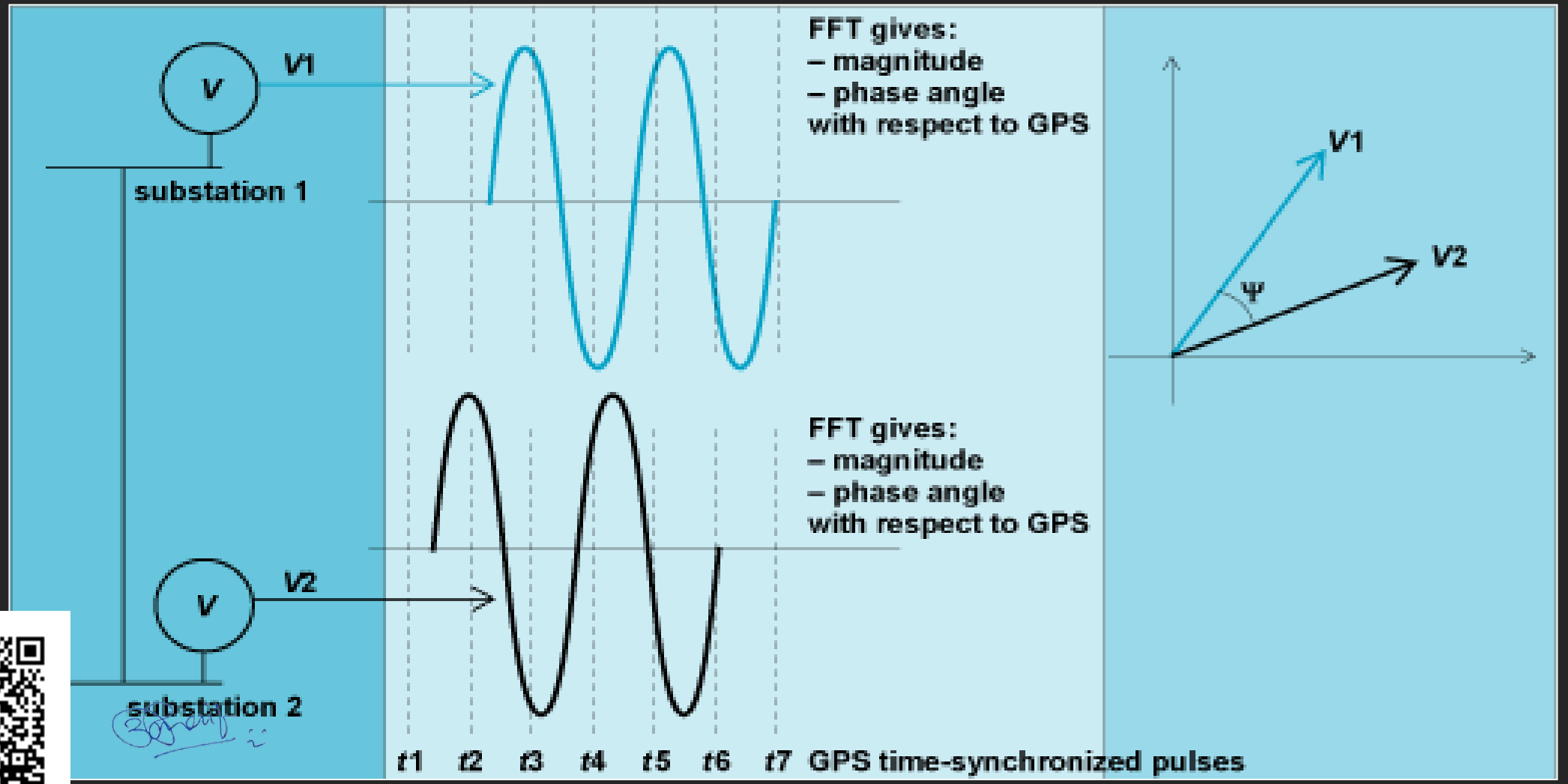
Existing Monitoring & Measurement System

- Existing SCADA based monitoring systems in Substations



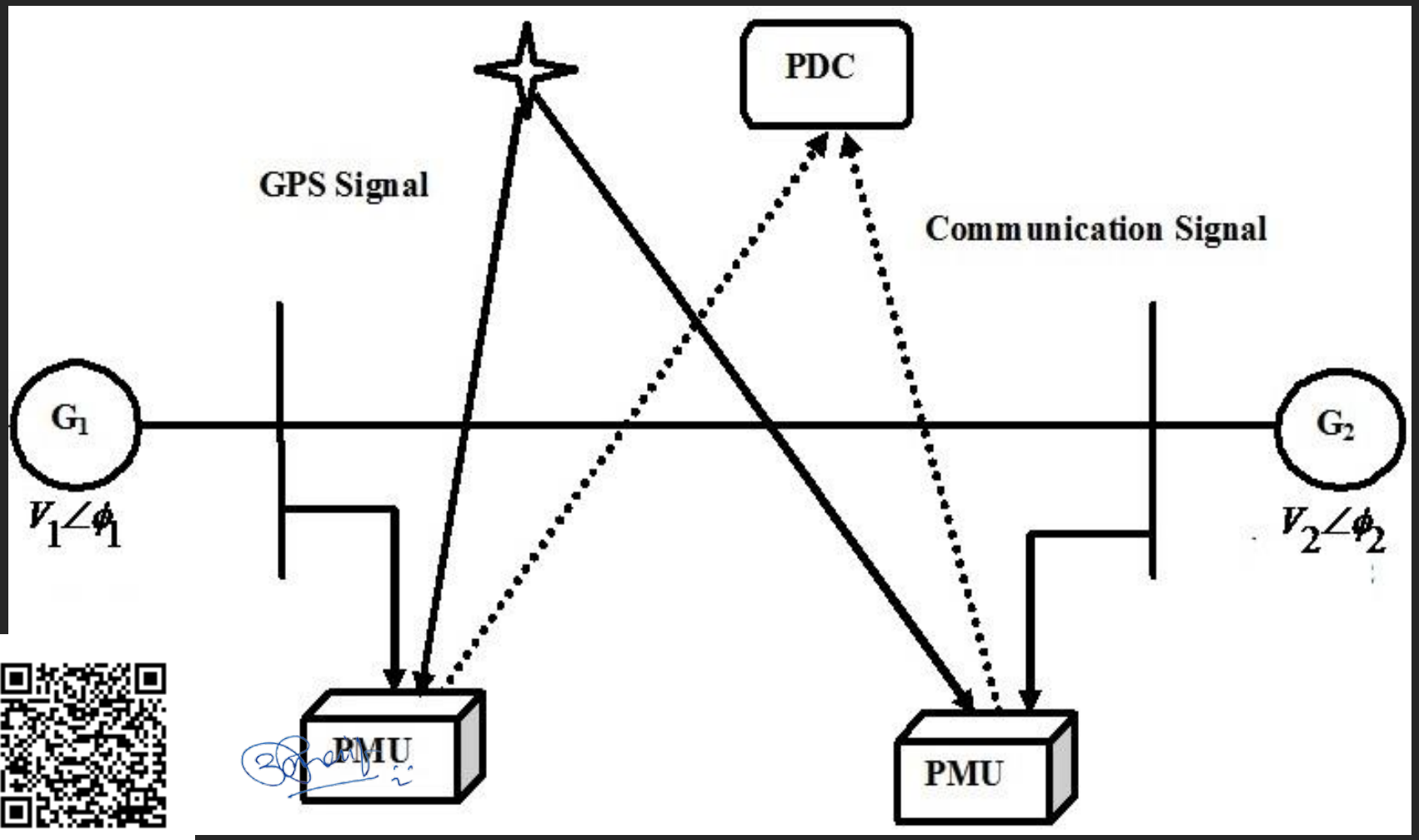
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Synchrophasor



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WAMS using Phasor Measurement Unit (PMU)



- Synchrophasor standard IEEE C37.118.1-2011
- Communication protocol IEC61850

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Benefits of using WAMS

- Time synchronized measurements of electrical quantities like voltage, current, frequency, ROCOF etc.
- System Awareness and monitoring
- Prevention of cascaded trippings that may leads to Blackouts
- Mitigation of the effects of hidden failures
- Assuring an appropriate balance between protection's dependability and security

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Challenges faced by Existing Electrical protection system penetrated with RES

- Blinding in Protection
- False Tripping
- Islanding problem
- Loss of Coordination
- unsynchronised reclosing
- varying Short-circuit levels

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Need for Adaptive Protection

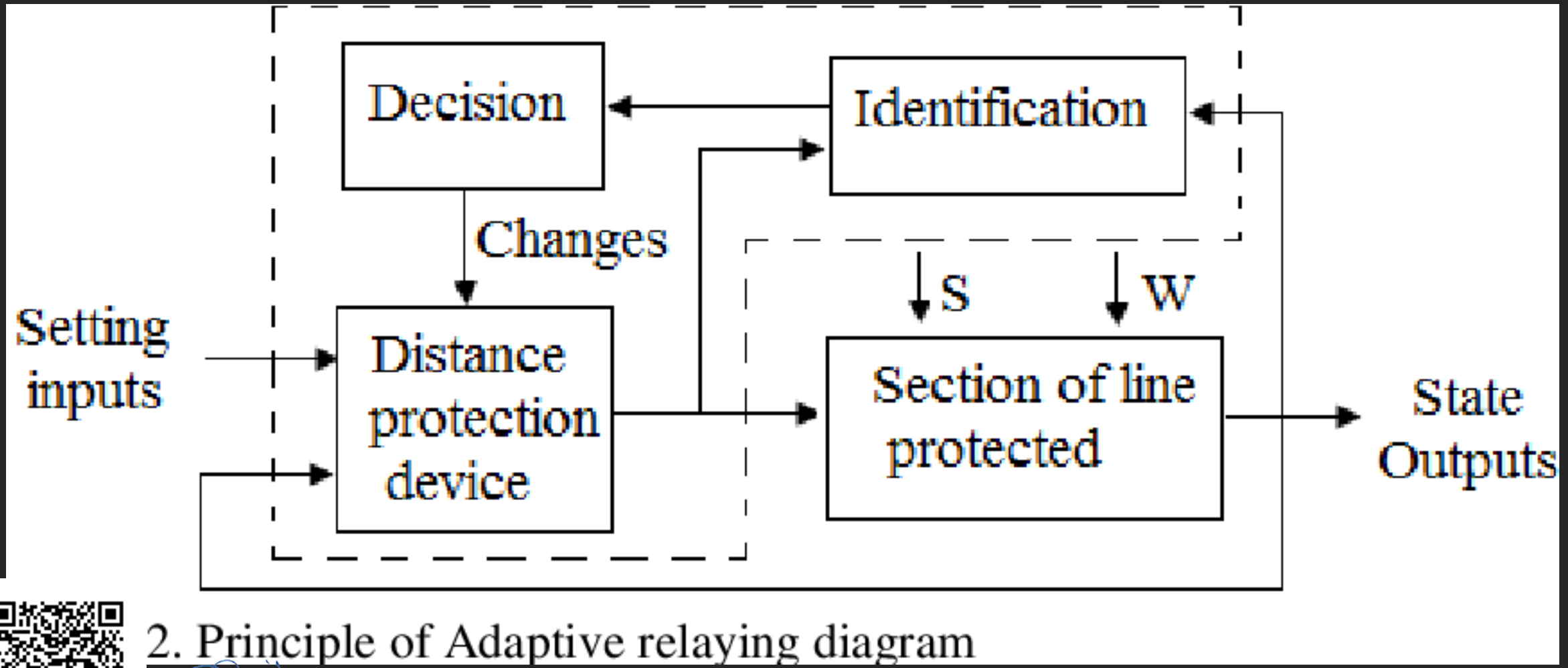
- System Integrity and Protection Schemes (SIPS)
- Current protection schemes in T&D systems is based on static and numerical relays.
- In transmission lines, distance protection and overcurrent protection is commonly used.
- n modify its own relay settings in response to system conditions
  d the system's current running state

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Why Adaptive protection?

- Rapid resolution of issues such as islanding of DGs, short circuit faults, sudden load changes etc.
- Optimized relay coordination pertaining to the changes in the network
- System restoration and security

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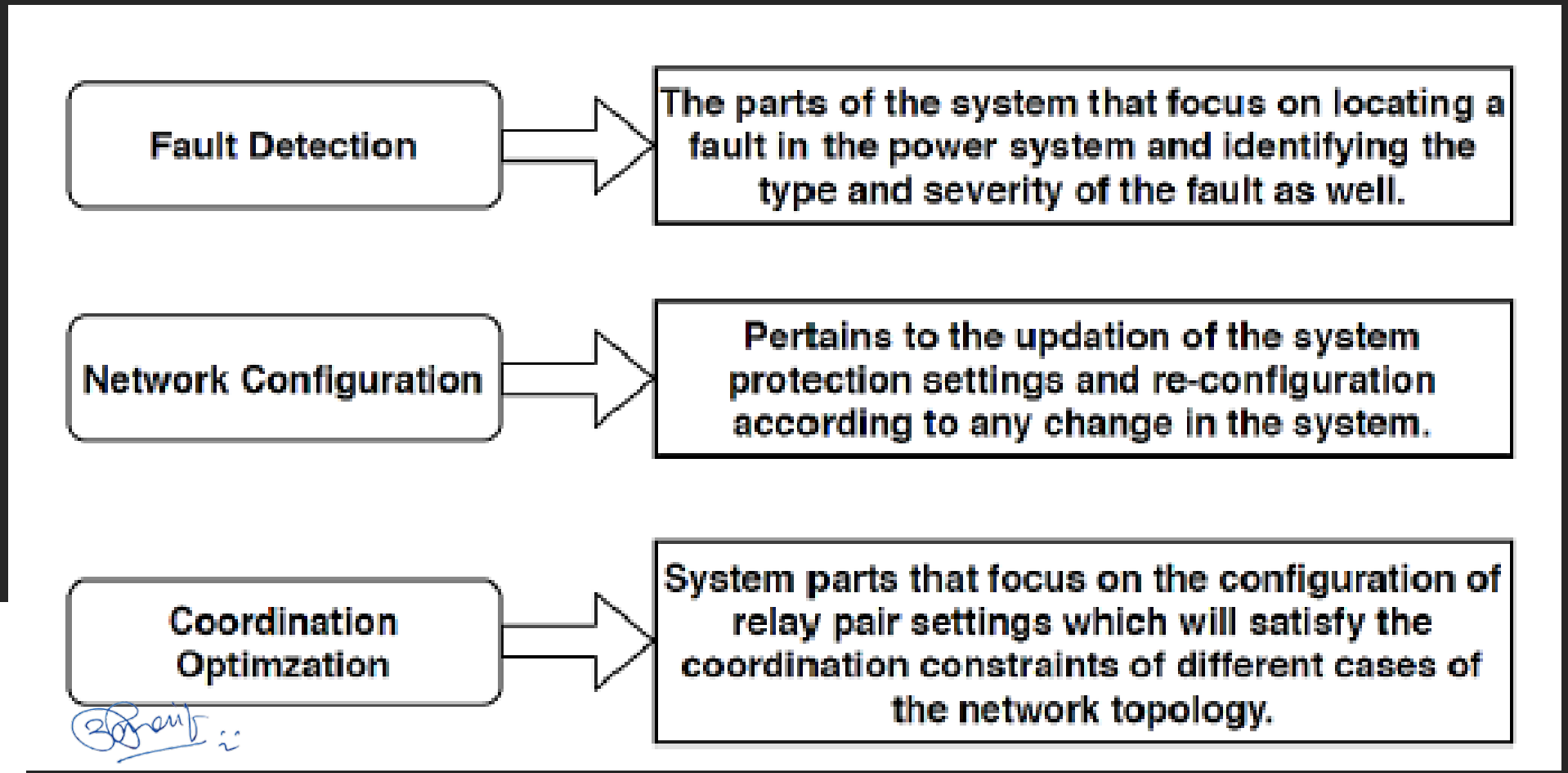


2. Principle of Adaptive relaying diagram

Source: Switchgear and Protection by S.Rao

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Components of adaptive protection scheme



Source: Resource Policy, Elsevier

Signal Processing based protection scheme approaches

Source: Resource Policy, Elsevier

Methods	Fault detection features	Advantages	Limitation
WWT and Decision Tree	• WWT is used to compute Approximation, Detail, and the peak value of the WT coefficient	• Fast • Intelligent • High accuracy about accuracy is 92.1%	• Limited time resolution capability • low performance for high impedance faults • Complex due to the increased number of features
Wavelet and Data-Mining	• WT coefficient energy • Entropy • standard deviation • DT for fault detection classification	• The response time falls within 1.5 cycles and 2.5 • Enhances the dependability and reliability of PDs	• Low performance for fault classification. • A large number of features. • HIF and fault location, are not considered
DWT, KNN, and DT	• WT coefficient • DT and KNN classifier	• High accuracy for fault classification	• Fault location and HIF are not included • A large data set
WT and DNN	• WT coefficient • Min and max value • Mean • Standard deviation • Skewness • Energy of coefficient • DNN	• Intelligent and fast fault detection, classification and phase identification • DWT and DNN • Without any communication • High accuracy	• HIF is not given. • Topology not consider • A great number of feature and data • complex • High computational burden

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S-transform	• spectral energy	• Detect shunt faults and HIFs • Fast • Better anti-noise performance	• Fault location and classification are not considered
Fast Recursive Discrete Fourier Transform Fuzzy-Logic	• RMS value of fundamental phasor • Use a fuzzy logic module for system variation detection	• Efficient fault signal estimations • Smart decision- making capability and adaptive	• Fault location, classification, and HIF is not consider
Differential and Hilbert–Huang Transform (HHT)	• Spectral energy • the difference in spectral energy	• Efficient • Detect HIF • Anti-noise performance	• Costly • The fault direction is not given
Mathematical Morphology (MM) Recursive Least-Square (RLS)	• Dilation and erosion • Zero-sequence currents • RLS method	• Fast • Accurate fault localization and classification	• HIF detection are not considered • High calculation burden
WT and Shannon Entropy	• Shannon entropy • Fuzzy logic	• Fast	• Fault direction, localization, and HIF are not included
DWT	• Detail and approximation • HIF detection	• Efficient • HIF faults are identified	• Fault direction and classification is not considered • The computational burden is high
DFT and DT	• Amplitude and Phase angle • DT and SVM	• Fast and intelligent • High Performance	• Fault location, HIF and topology changes are not given

Source: Resource Policy, Elsevier

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Methods	Features	Advantages	Limitations
Fuzzy interface systems (FISs)	• Teager Energy operator • Two FISs	• The response time 1/4 –1 cycle. • Fault detection/classification • HIF detection	• Fault localization and topology changes are not considered • complex in nature
Discreet Wavelet (WT) and (ANFIS)	• energy coefficient • ANFIS is used to identify the fault zone	• Fast and intelligent • Response time is 1/4 cycle	• complex computation • Large data set • Fault classification • HIF is not included • Islanded operation
DT- Fuzzy Rule	• S-transform is used to compute statistical features • Energy • Mean • Standard deviation • Entropy	• Fast	• A large number of the features • High computational burden • Fault location and HIF are not consider
Hybrid (ANN-SVM)	• Adaptive protection scheme for MGs	• Adaptive • Self-learning • Self-training • Fault location	• A large number of data sets • Complex in nature • High Computational burden and training
Fuzzy-Neuro	• Fuzzy-Neuro • Symmetrical components	• Fast • Accurate • Robust	• Network changes affect the threshold values. • Complex • Large fault data
ve Fuzzy Logic	• Zero sequence component of current signals	• Fault detection, classification • Phase identification • Dynamic changes	• Communication failure • Costly due to communication system • HIF not included

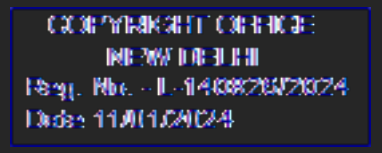
Source: Resource Policy, Elsevier

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Challenges in Adaptive protection algorithms

Research problem focuses on design of Adaptive protection scheme for renewable energy sources integrated transmission line using wide area measurement technology to provide solution towards issues of,

- Limited capacity for time resolution
- Poor performance for faults with high impedance
- High computational burden
- Fault location (travelling wave based) and classification
- mplex algorithm and computation structure



Thank You..!!



