PROTECTION LIFE CYCLE MANAGEMENT

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Grid Automation

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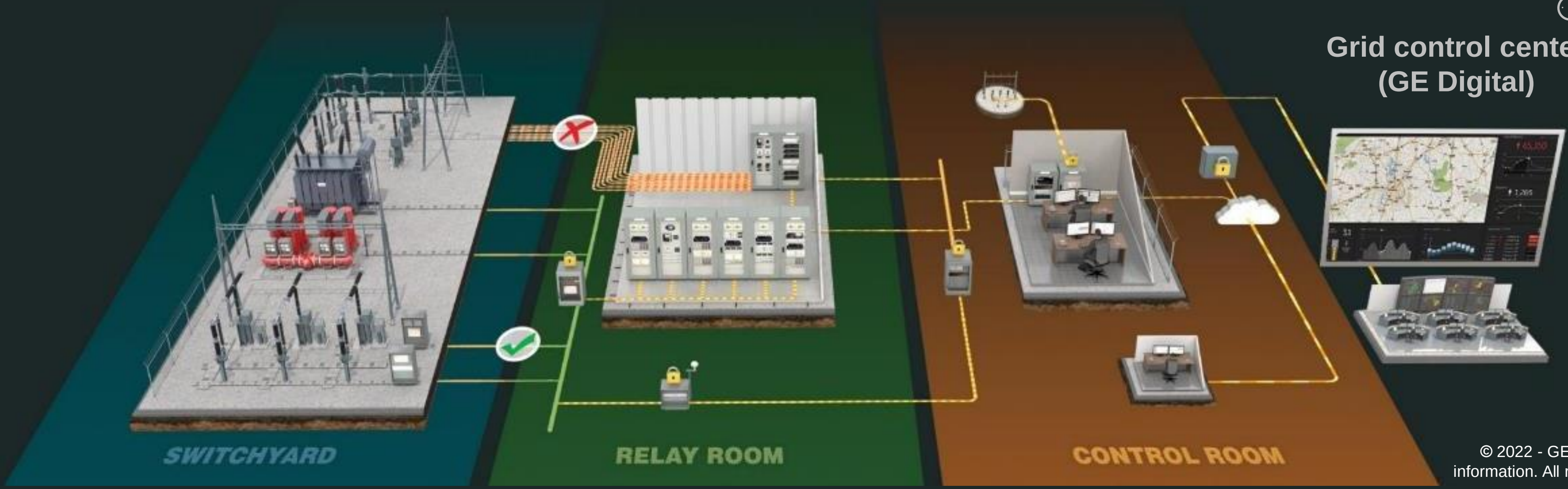
μs
MONITOR
Edge devices, Data acquisition for protection or asset management

ms
PROTECT
Analyze, instant decisions, send commands to switchyard to execute

100 ms
CONTROL
Operator interface, substation management

s/min
Grid control center (GE Digital)



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ms
COMMUNICATE
Share operational data inside substations, between substations and with central control system

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Pre 1900 – 1980`s

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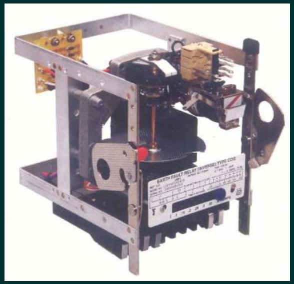
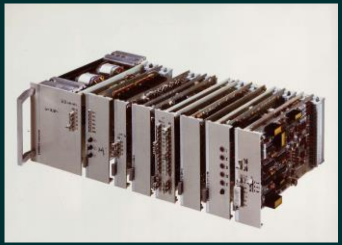
pre1900’s
- Self contained device such as fuses

1900’s
- First overcurrent relay
- Coincides with CB and CT/VT
- Electromechanical / Induction disc – single function

1950’s
- Solid state relays
- Electronic components

1980’s
- Microprocessor based
- Size reduction
- More flexibility





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1990`s – 2020`s

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1990's

- Numerical based
- Serial Communication (proprietary)
- Multifunction
- Software Design – reduced secondary wiring

2000's

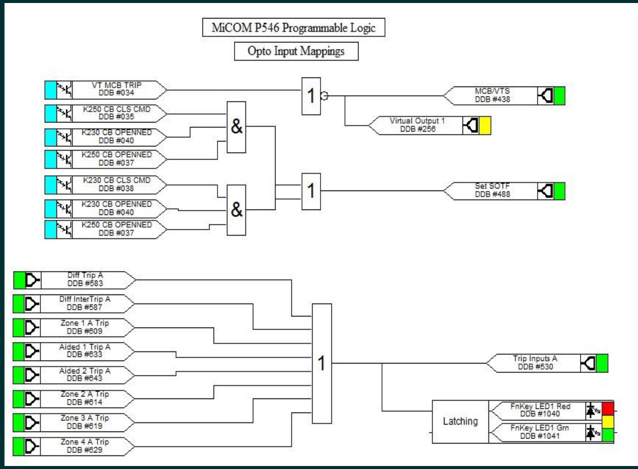
- Interoperability and open standards
- WAPAC`s
- Communications is an integral part of protection system

2010's

- Digital Substation – Reduced Footprint
- Use of fibre optic / ethernet comms
- Non conventional IT`s

2020's

- Centralised / Virtualised Protection
- Reduced limits on location
- Digital twins



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Protection - Why is it needed?

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All Power Systems may experience faults at some time.

PROTECTION IS INSTALLED TO :

Detect fault occurrence and isolate the faulted equipment.

SO THAT :

Damage to the faulted equipment is limited;

Disruption of supplies to adjacent unfaulted equipment is minimised.

PROTECTION IS EFFECTIVELY AN INSURANCE POLICY - AN INVESTMENT AGAINST DAMAGE FROM FUTURE FAULTS.

DAMAGE LIMITATION

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Current Transformer Function

- Reduce power system current to lower value for measurement.
- Insulate secondary circuits from the primary.
- Permit the use of standard current ratings for secondary equipment.

REMEMBER :

The relay performance DEPENDS on the C.T which drives it !

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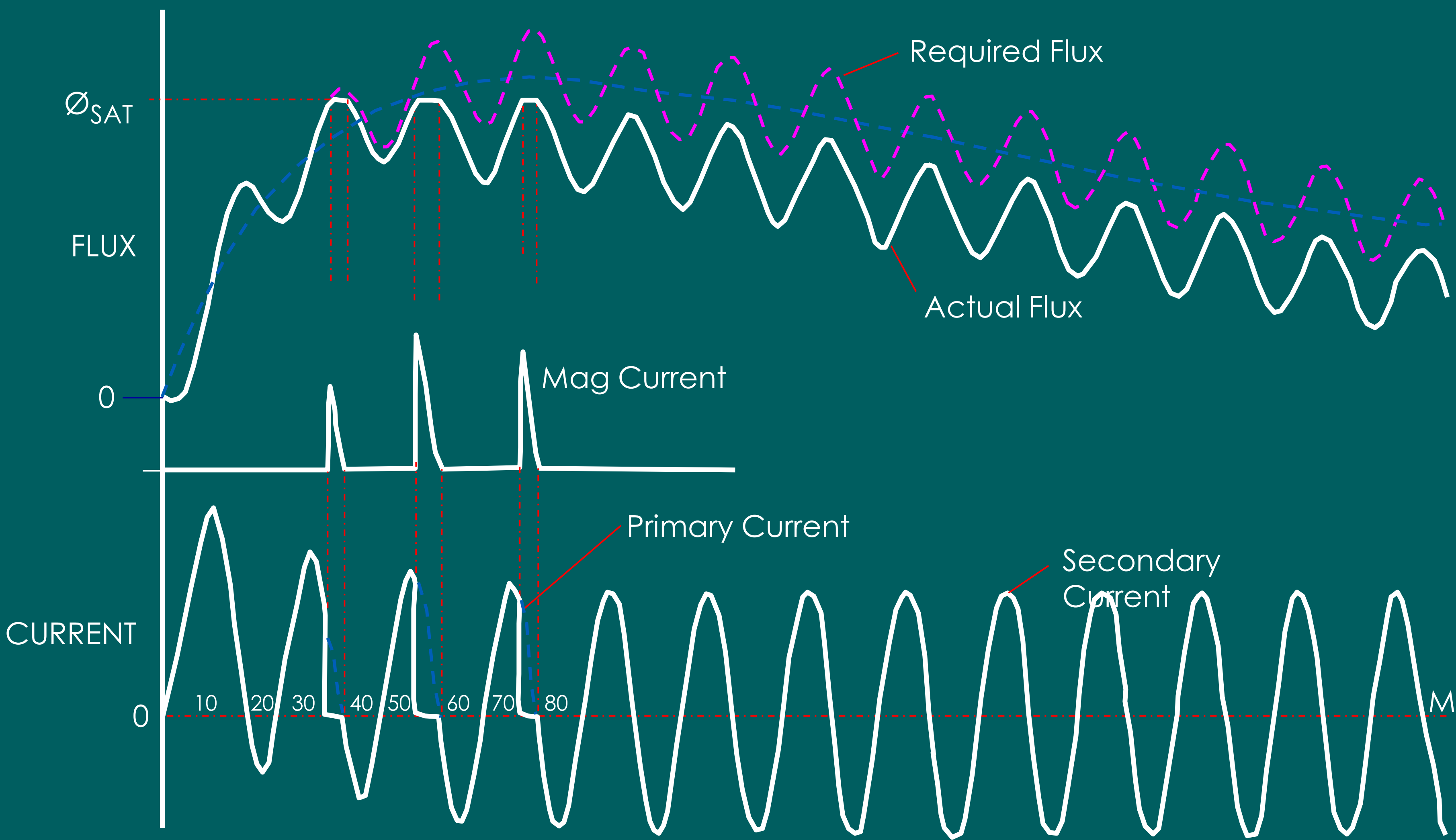
TRANSIENT SATURATION : RESISTIVE BURDEN



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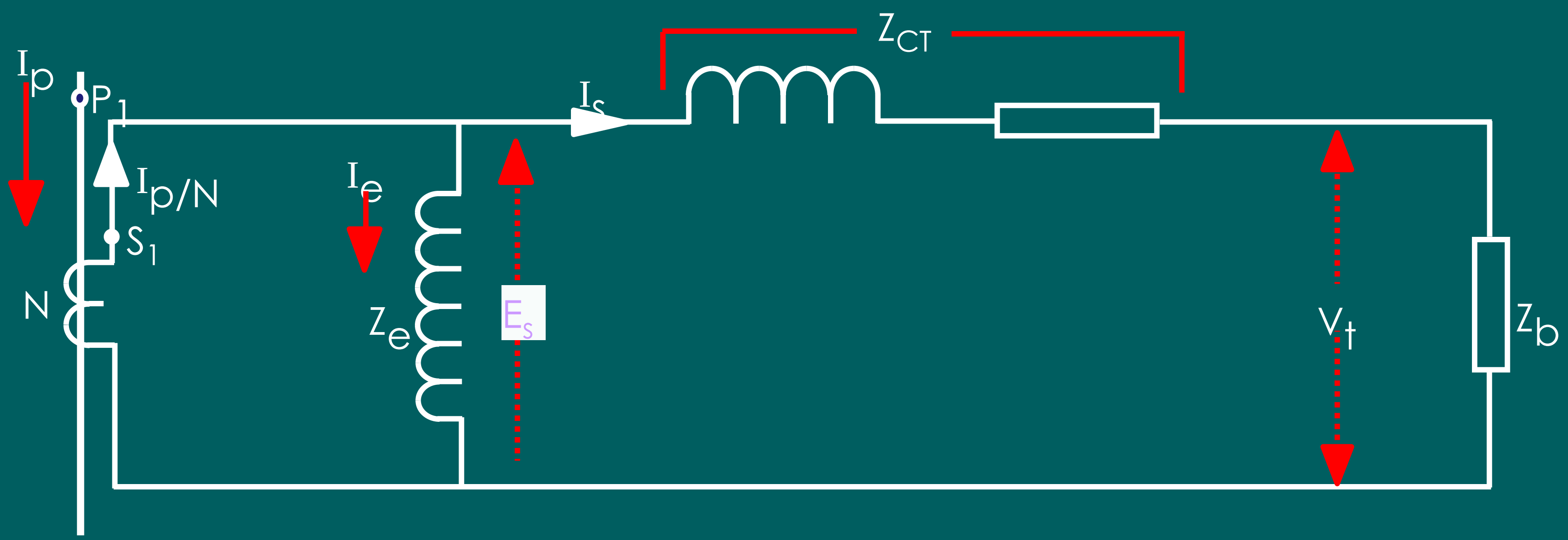
C.T. EQUIVALENT CIRCUIT



I_p	=	Primary rating of C.T.
N	=	C.T. ratio
Z_b	=	Burden of relays in ohms (r+jx)
Z_{CT}	=	C.T. secondary winding impedance in ohms (r+jx)
Z_e	=	Secondary excitation impedance in ohms (r+jx)
I_e	=	Secondary excitation current
I_s	=	Secondary current
E_s	=	Secondary excitation voltage
V_t	=	Secondary terminal voltage across the C.T. terminals

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CT`s Failure – Never Open Circuit a CT

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Protection – (You have a part to play – not just Engineering)

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Protect life and the system	
Understand the whole power system and its components	• Steady State • Fault Conditions • End to End
Stay up to date with technology and codes of practice	• Emerging Technologies • Standards / Legislation • Policy
Life Cycle Management	• Project Management • EHS

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Protection Scheme Design, Setting, Installation & Commissioning

- Effectiveness of the protection scheme depends on the initial scheme engineering, such as:

  - **Design** - Contingency through redundancy and backup.
  - **Settings** - Start signals mapped to trips, etc.
  - **Installation** - e.g. supply to panel from wrong side of fuse.
  - **FAT/SAT** - Calibration of Test Equipment
  - **Commissioning** - CT shorting left on after test.

- **The vast majority of protection failures can be attributed to the engineering (Human Error)**

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Estimated lifetime of assets in a Distribution Network

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▶ Dealing with an ageing and mixed technology system

- Sub Station 50-60+ Years
- Transformer 40-50+ Years
- Switchgear 30-50+ Years
- Relay Protection 20-25+ Years
- Control System 20 -25+ Years

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Full Life Cycle

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- **Asset Management is the art of balancing the following:**
  - **Performance** – system availability and its competence
  - **Risk** – the exposure to negative events
  - **Cost** – the resource required to achieve the performance and moderate the risk

- **If all of the above have been evaluated and are considered beyond acceptable limits, then Protection Refurbishment should be considered.**

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Ongoing System Expansion & Modification

Lifetime may require protection modifications, due to:

- Increased fault levels
- Load expansion or contraction
- Regulatory changes

Consequences of modifications not fully appreciated and may lead to:

- Unnecessary protection operations
- Under protected primary plant
  - Risk to human life
  - Capital cost of plant replacement

Regular protection audits may mitigate some of the above risks.

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Ongoing Maintenance

Objective is to maximise lifecycle of protection scheme

- Routine maintenance is essential to identify potential failures before they become critical or permanent
- Frequency depends on environment, criticality and resources

Poor maintenance may result in unidentified protection failure or cause premature failure

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Consequences of Protection Relay Failure

Protection relay failure can occur at every stage of the lifecycle

Incorrect initial system engineering

Poor maintenance

Failure to fully capture system modifications

The consequences can be catastrophic

Unnecessary disruption in supplies

Damage to equipment due to excessive operating times

Incorrect operation of plant

Fire & explosion due to the fault withstand times being exceeded

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Types of Protection Refurbishment and Refitting

- There are various methods of replacing existing protection equipment.

- 1) ‘Plug & Play’ Retrofit
- 2) Single Device Replacement
- 3) Cubicle Door Replacement
- 4) 19” Rack Replacement
- 5) Cubicle Replacement

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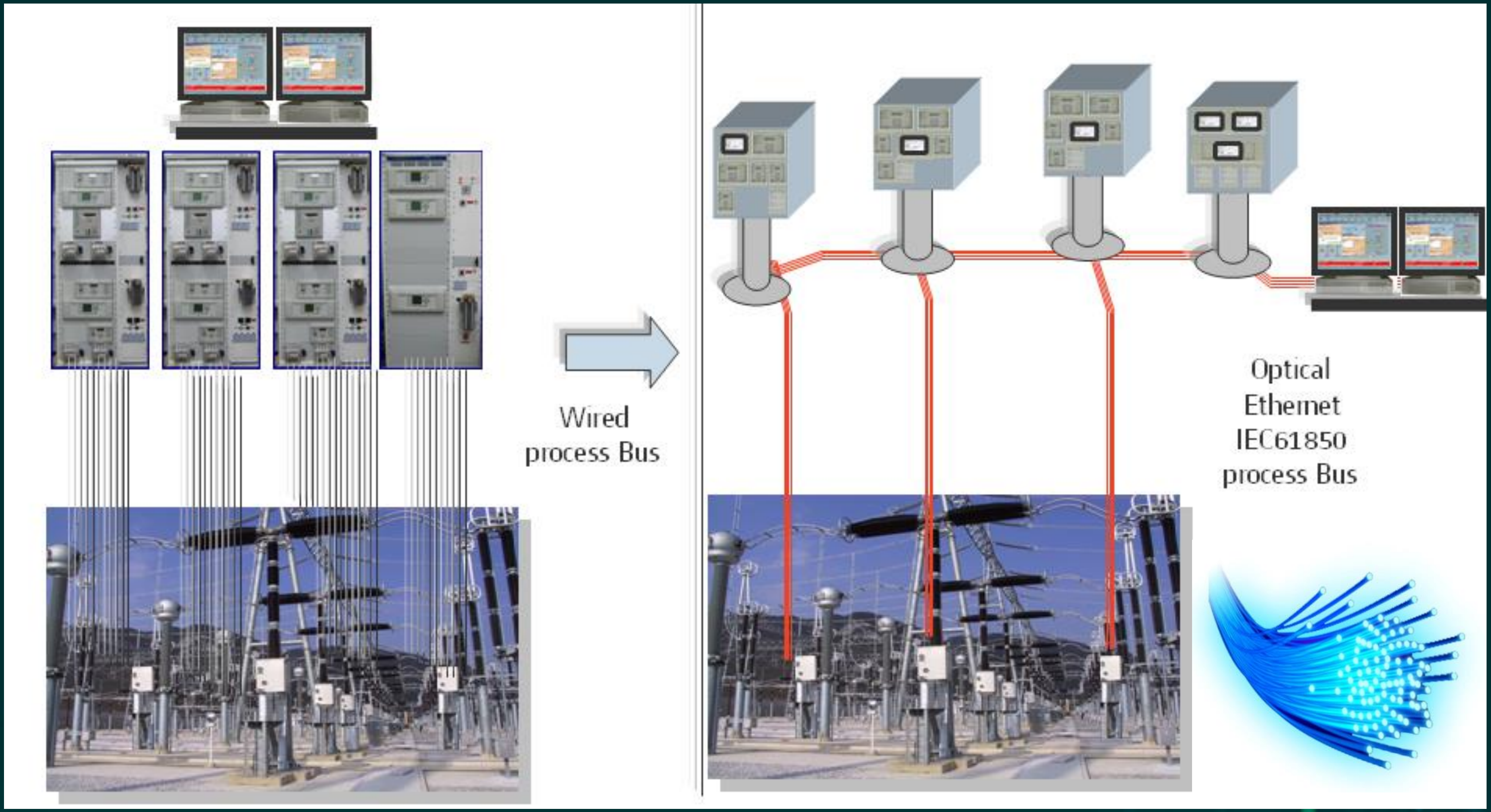
Digital Substation



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Future or Today?

Requirements to protect a power system?:

- **Measure power system quantities**
- **Perform computation**
- **Issue commands**
- **Feedback / Monitoring**
- **Store data**

Imagine:

- **Not limited by distance – no copper**
- **No need for dedicated facilities i.e. relay rooms ?**
- **Use any hardware / software platform – cloud or similar**
- **Interchangeability – completely open system**

Totally remote monitoring, operation, control, diagnostic and intervention / restoration.

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THE ENERGY TRANSITION

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DECARBONIZATION

- Fossil fuel generation retirement
- Renewable generation adoption

ELECTRIFICATION

- Industrial processes
- Transportation

ZEV = zero emissions vehicles

THE ELECTRIC GRID IS AT THE HEART OF THE ENERGY TRANSITION AND IS NOT PREPARED TO SUPPORT THE CHANGE

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THE GRID OF THE FUTURE

	FUEL	GENERATOR	GRID	DEMAND
FROM	• Easy to control • Dispatchable on demand	• Provides inertia • Can start grid from zero • Higher fault levels	• One-way flow of electricity from transmission to distribution	• Relatively predictable
TO	• Variable & Intermittent • Limited dispatchability	• Limited natural inertia & ability to start grid • Fast versatile controls • Lower fault levels	• Two-way flow with distributed generation feeding transmission	• Mobile and less predictable distributed generation

NEED FOR THE GRID TO TRANSITION TO A DIFFERENT WAY OF PRODUCING AND CONSUMING ENERGY

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GRID DIGITALIZATION STAGES

DECISION

1. Operator rule-based
2. Operator data-driven
3. Operator with AI supervision
4. Full automation

SOLUTIONS

1. Grid primary assets & DERs digitization
2. Monitoring & Control systems virtualization
3. Advanced automation applications
4. Autonomous operations & maintenance

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TECHNOLOGY INNOVATION

ADVANCED ALGORITHMS

- Wide area protection – DSR / DLR
- ZAC
- Dynamic System Rating
- Power Management and Optimization

VIRTUALIZATION

- Protection and control
- Realtime performance

CYBERSECURITY AND CLOUD

- Secure boot / root of trust
- Secure comm protocols
- Token-based authentication

ARTIFICIAL INTELLIGENCE

- Fault identification
- Predictive and prescriptive diagnostics
- Autonomous reliable operations

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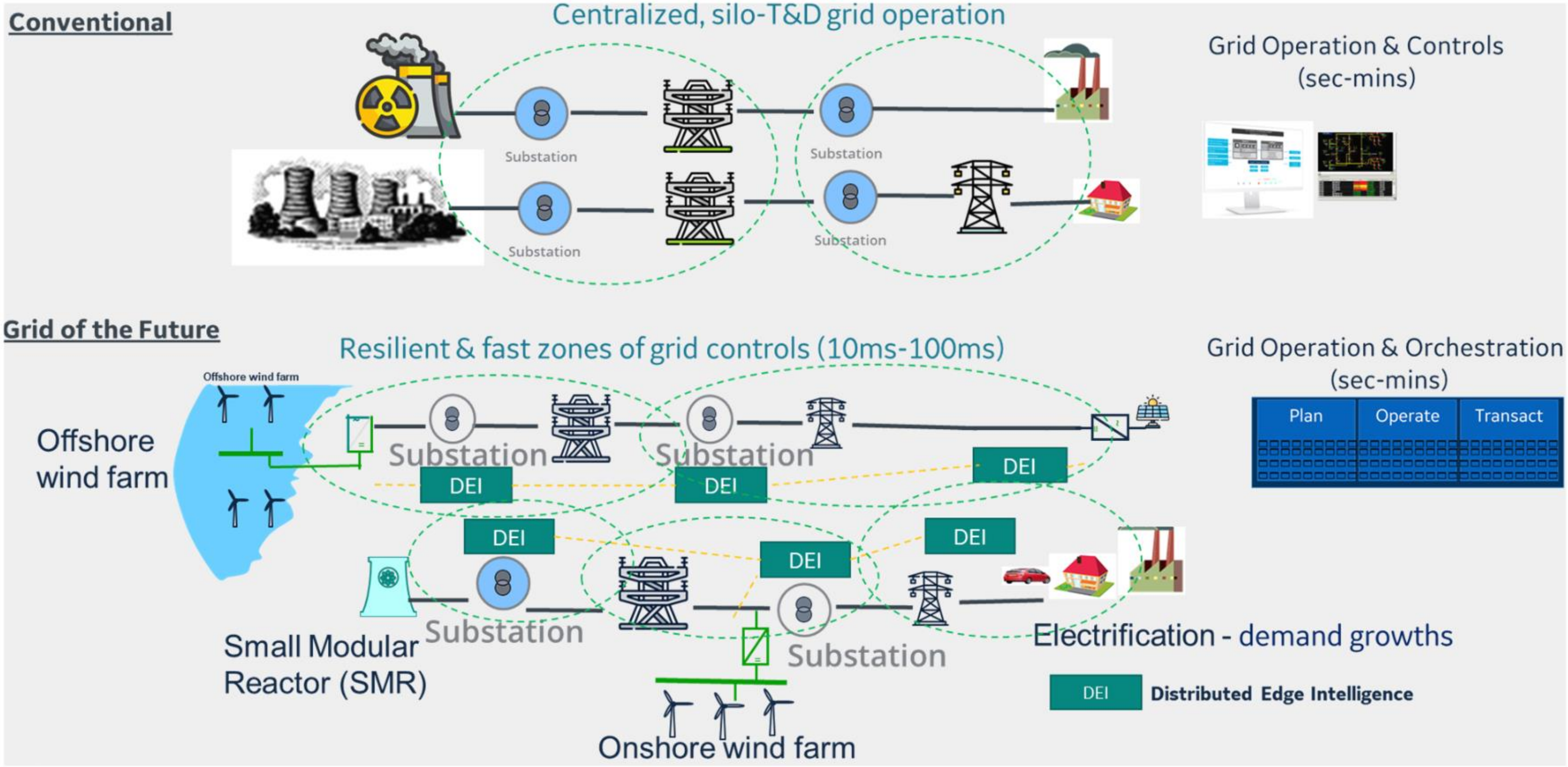
Enabling Energy Transition with Distributed Edge Intelligence



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Questions ?

Thank you