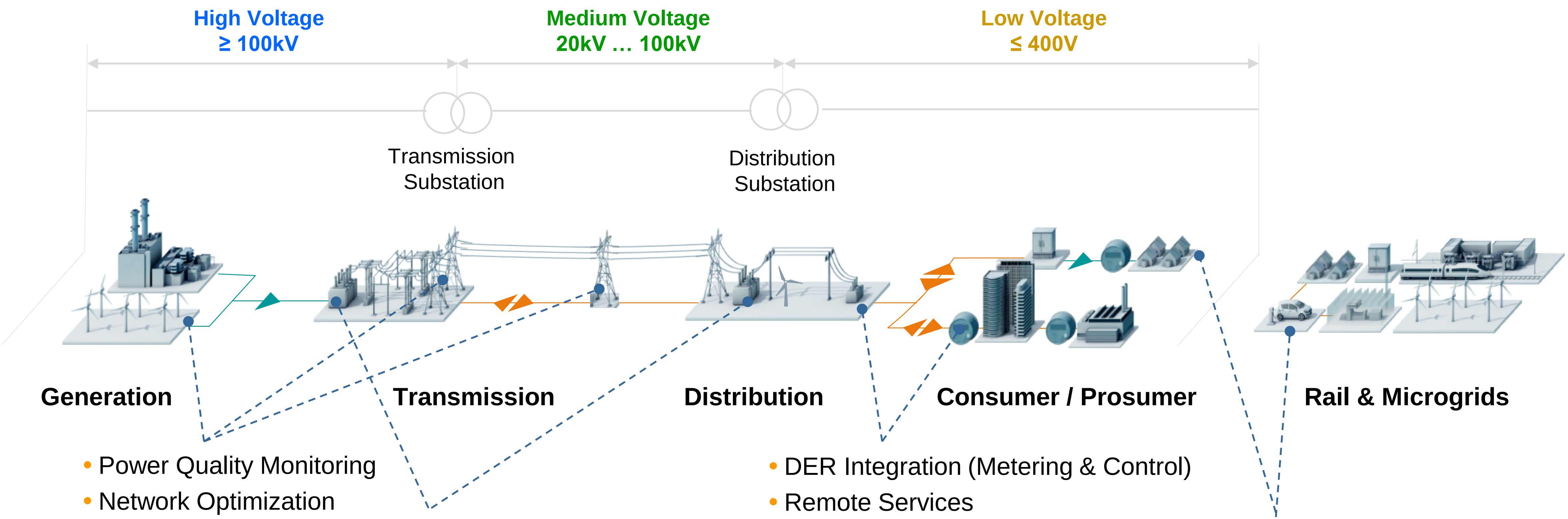
Panel Discussion

Energy Data Exchange and Adaptive Consumption

Moderator
Rainer Falk, Steffen Fries, Siemens AG, Germany

Panelists
Vivian Sultan, California State University Los Angeles, USA
Michael Kuhn, Otto von Guericke University Magdeburg, Germany
Eric Veith, OFFIS - Institut for Information Technology, Germany
Mark Apperley, University of Waikato, New Zealand
Michael Negnevitsky, University of Tasmania, Australia

Digital Grid – a critical infrastructure
Power system value chain and use case examples



High Voltage
≥ 100kV

Medium Voltage
20kV … 100kV

Low Voltage
≤ 400V

Transmission
Substation

Distribution
Substation

Generation

Transmission

Distribution

Consumer / Prosumer

Rail & Microgrids

- Power Quality Monitoring
- Network Optimization

- Substation Automation
- Inter Control Center Communication
- Remote Maintenance and Service

- DER Integration (Metering & Control)
- Remote Services
- Flexibility Handling

- Connecting Electric Vehicles to the Charging Infrastructure as part of the Digital Grid
- Interactions with microgrid, to support local energy autonomy

challenges & questions for discussion

Starting points for the panelists

- Decentralized Energy Resources – Enable resilience through Microgrids and Islanding
- Adapting power consumption of devices to their real need
- Secure system interaction in digital grids – A necessary prerequisite to support resilience
- Data collection (customer consumption profiles)
- New use cases in the digital grid – Examples like electric vehicles, microgrids, and flexible loads influence system reliability and require increasing resilience. How can new technologies like AI be leveraged to support?
- How do the requirements for increased system interconnection on one hand and the rising demand for energy autonomy influences on system interaction (load distribution, secure communication, …)
- Which further challenges exist?

topics from the panelists

Vivian Sultan, California State University Los Angeles, USA

- Energy data and adaptive consumption for grid reliability – How to use adaptive response and load flexibility to handle Demand Response

Michael Kuhn, Otto von Guericke University Magdeburg, Germany

- Energy-efficient high-performance computing: How to reduce power consumption in HPC systems using schedulers?

Eric Veith, OFFIS - Institut for Information Technology, Germany

- Adaptive Consumption: The Flexibility is in the Grid

Mark Apperley, University of Waikato, New Zealand

- Community Energy Systems – Extending the Community

Michael Negnevitsky, University of Tasmania, Australia

- A practical approach to data collection and observability analysis in distribution networks – Using confidence values to better estimate network load

Rainer Falk, Steffen Fries, Siemens, Germany

- Secure system interaction in digital grids

Panel Contribution

Secure system interaction in digital grids

Rainer Falk, Steffen Fries, Siemens AG, Germany

Our industrial society confesses a growing demand for IT-Security

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IT Security trends are determined by drivers such as

- Changes in industrial infrastructures (Digitalization)
- Increasing use of networked embedded systems
- Increasing device-to-device communication
- Need to manage intellectual property

and changing boundary conditions

- Increasing international organized crime
- Privacy
- Compliance enforcement
- Cyber war fare
- Cloud/Virtualization
- Data mining and smart data analytics
- Smart mobile devices
- ….

Digital Grid – a critical infrastructure
Power system value chain and use case examples

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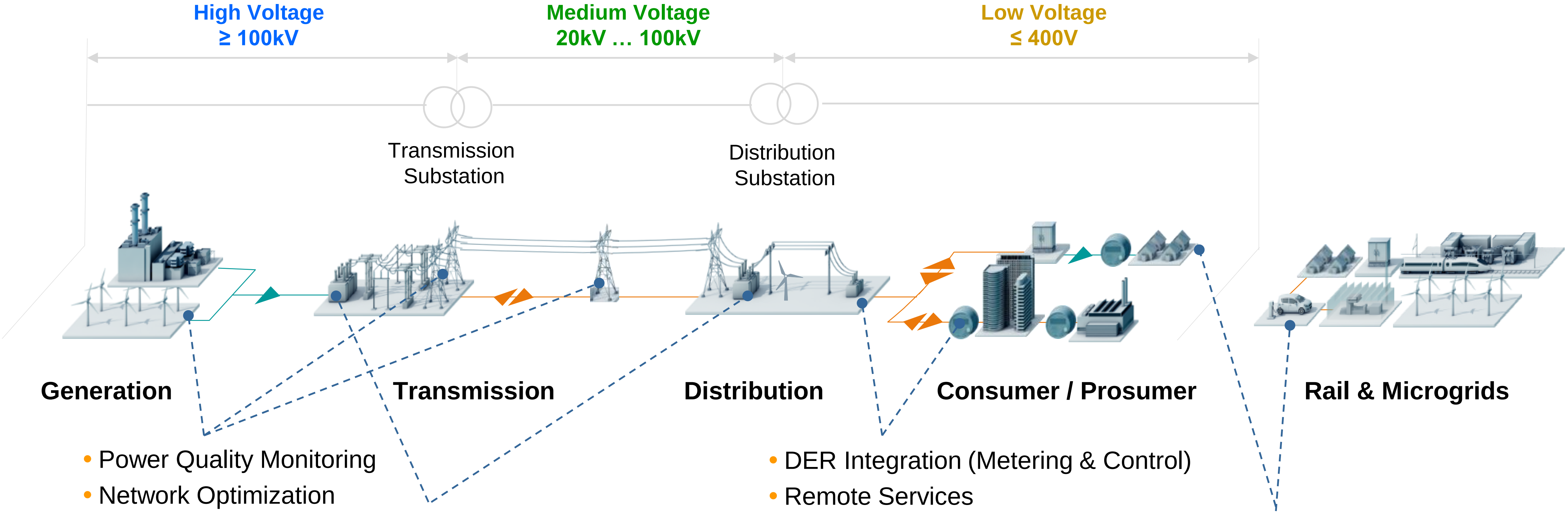

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- Connecting Electric Vehicles to the Charging Infrastructure

Typical data exchanged in Digital Grid applications and their security impact

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Information asset	Description, potential content	Security relation to
Customer ID and location data	Customer name, identification number, schedule information, location data	**customer privacy**
Meter Data	Meter readings that allow calculation of the quantity of electricity consumed or supplied over a time period and may be used for controlling energy loads but also for interactions with an electricity market.	**system control and billing**
Control Commands and Measurements	Actions requested by one component of other components via control commands. These commands may also include Inquiries, Alarms, Events, and Notifications.	**system stability and reliability and also safety**
Configuration Data	Configuration data (system operational settings and security credentials but also thresholds for alarms, task schedules, policies, grouping information, etc.) influence the behavior of a component and may need to be updated remotely.	**system stability and reliability and also safety**
Time, Clock Setting	Time is used in records sent to other entities. Phasor measurement directly relates to system control actions. Moreover, time is also needed to use tariff information optimally. It is also used in security protocols, e.g., when verifying the validity of using certificates.	**system control (stability and reliability and also safety) and billing**
Access Control Policies	Components need to determine whether a communication partner is entitled to send and receive commands and data. Such policies may consist of lists of permitted communication partners, their credentials, and their roles.	**system control and influences system stability, reliability, and also safety**
Firmware, Software, and Drivers	Software packages installed in components may be updated remotely. Updates may be provided by the utility (e.g., for charge spot firmware), the car manufacturer, or another OEM. Their correctness is critical for the functioning of these components.	**system stability and reliability and also safety**
Tariff Data	Utilities or other energy providers may inform consumers of new or temporary tariffs as a basis for purchase decisions.	**customer privacy and also competition**

How to provide appropriate security?
Cyber security needs a holistic methodology

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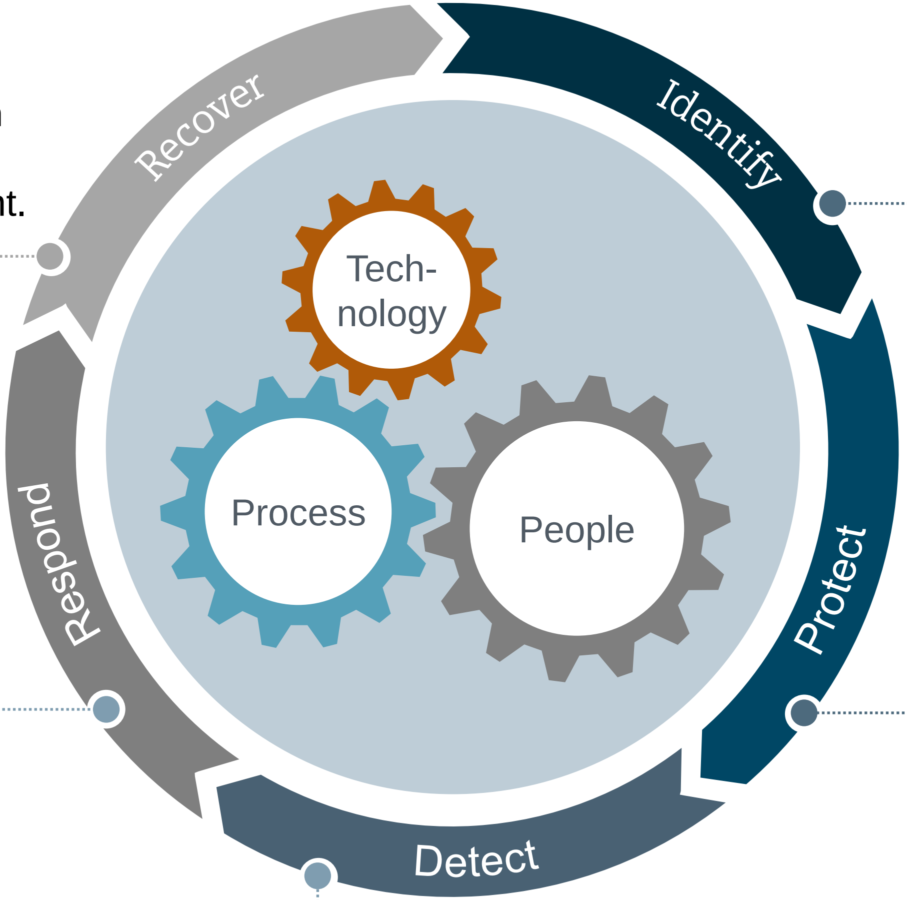

Recover
Creating plans for resilience and **restoration** of any capabilities or services that were impaired due to a cyber security related event.

Identify
Understanding the business context, the resources that support critical functions and the related cyber security risks.

Respond
Taking action against detected cyber security related events. Supports the ability to contain the impact of a potential event.

Protect
Protection of critical infrastructure service, e.g., energy supply by safeguarding the overall system.

Detect
Rapid **identification** of the occurrence of a cyber security related event.

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Based on NIST
Cyber Security
Framework

Digital Grid as critical infrastructure is addressed through standards and regulative requirements (examples, global view)

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IEC ISO

- IEC 62351 – Power systems management and associated information exchange – Data and communications security
- IEC 62443 – Security for industrial automation and control systems
- ISO/IEC 15118 – Road vehicles -- Vehicle to grid communication interface

ISO JTC 1 IEC INFORMATION TECHNOLOGY STANDARDS

- ISO/IEC 27001 – Information technology - Security techniques - Requirements
- ISO/IEC 27002 – Code of Practice for information security management
- ISO/IEC 27019 –Information security controls for the energy utility industry

IEEE

- IEEE 1588 – Precision Clock Synchronization
- IEEE 1686 – Intelligent Electronic Devices Cyber Security Capabilities

IETF

- RFC 4301 – Security Architecture for the Internet Protocol
- RFC 5246 – Transport Layer Security TLS v1.2
- RFC 8446 – Transport Layer Security TLS v1.3

FERC FEDERAL ENERGY REGULATORY COMMISSION

Homeland Security

NERC NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

- Critical Infrastructure Protection CIP 001-014
- Executive Order EO 13636 improving Critical Infrastructure Cyber Security
- IoT Cybersecurity Improvement Act 2017

Bundesamt für Sicherheit in der Informationstechnik

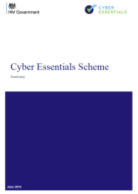
- IT Security Act
- B3S Standards
- BNetzA Security Catalogue
- German Energy Act

- Network Information Security Directive

ANSSI Agence nationale de la sécurité des systèmes d'information

- Critical Infrastructure Protection
- Certification and Key Measures

CPNI Centre for the Protection of National Infrastructure



- Cyber Essential Scheme
- Direct adaptation of European NIS Directive and GDPR (General Data Protection Regulation

Note: the stated organizations and standards are just examples and are not complete

Standards and Regulations
ISO/IEC 270xx Series – Information Security Management System (ISMS)

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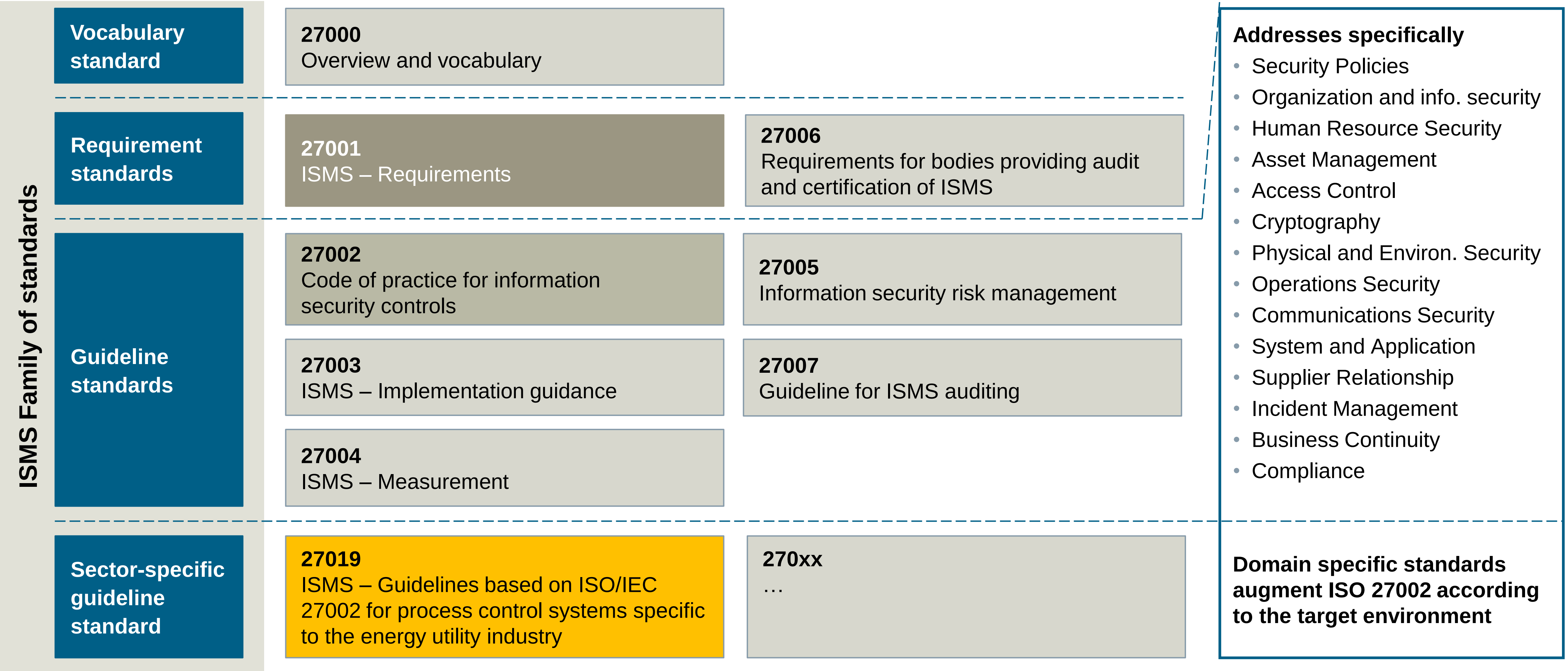


ISMS Family of standards

Vocabulary standard

27000
Overview and vocabulary

Requirement standards

27001
ISMS – Requirements

27006
Requirements for bodies providing audit and certification of ISMS

Guideline standards

27002
Code of practice for information security controls

27005
Information security risk management

27003
ISMS – Implementation guidance

27007
Guideline for ISMS auditing

27004
ISMS – Measurement

Sector-specific guideline standard

27019
ISMS – Guidelines based on ISO/IEC 27002 for process control systems specific to the energy utility industry

270xx
…

Addresses specifically
- Security Policies
- Organization and info. security
- Human Resource Security
- Asset Management
- Access Control
- Cryptography
- Physical and Environ. Security
- Operations Security
- Communications Security
- System and Application
- Supplier Relationship
- Incident Management
- Business Continuity
- Compliance

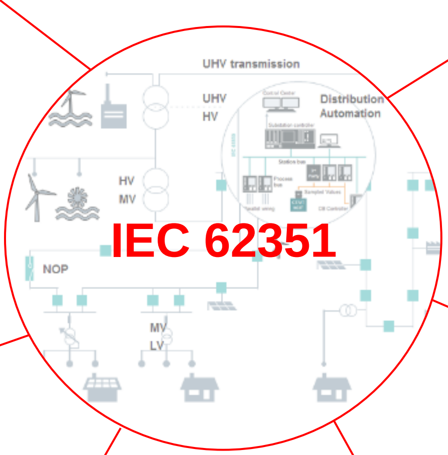
Domain specific standards augment ISO 27002 according to the target environment

IEC 62443 Security for Industrial Automation and Control Systems addresses the complete value chain from product to service

- Addresses
  - Operator
  - Integrator
  - Product Supplier
- in terms of
  - processes and
  - security capabilities
- and allows for
  - certification

General	Policies & Procedures	System	Component / Product
1-1 Terminology, concepts and models	2-1 Security program requirements for IACS asset owners 🟨 🟩	3-1 Security technologies for IACS	4-1 Secure Product Development Lifecycle Requirements 🟨 🟩
1-2 Master glossary of terms and abbreviations	2-2 Security Program Rating 🟨	3-2 Security Risk Assessment and System Design 🟨 🟦	4-2 Technical security requirements for IACS components 🟦 🟩
1-3 System security conformance metrics	2-3 Patch management in the IACS environment 🟨	3-3 System security requirements and security levels 🟦 🟩	
1-4 IACS security lifecycle and use-cases	2-4 Security program requirements for IACS service providers 🟨 🟩		
	2-5 Implementation guidance for IACS asset owners		

Cyber security is addressed in power system automation with IEC 62351 building on state of the art security technology



IAM – Authentication, Identification Authorization (RBAC) of Users/Devices
Focus: Usage of X.509 certificates

Secure communication between different actors (Ethernet, IP, serial)
Focus: Profiling of existing standards (e.g., TLS) and definition of security enhancements if necessary

Monitoring and audit of security relevant events
Focus: Application of established standards like syslog and SNMP

Key management of long term and session keys
Focus: Application of established certificate management (EST, SCEP) and key management (GDOI) protocols

Test case description for the specified security measures in the different parts of IEC 62351
Focus: Specification of conformity test cases

Guidance and support for securing power system
Examples comprise role based access control (RBAC), Moitoring of commuication connections, …

Cyber Security for Power System Automation – The Interplay of ISO/IEC 27001 / IEC 62443 / IEC 62351

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Cyber Security regulation are provided for instance by
- European NIS Directive and derived country specific laws
- US FERC for North America

ISO/IEC 27001
ISO/IEC 27002

Asset Owner Operator — IT Infrastructure

ISO/IEC 27001

ISO/IEC 27019

Integrator — IT Infrastructure

IEC 62443-2-4

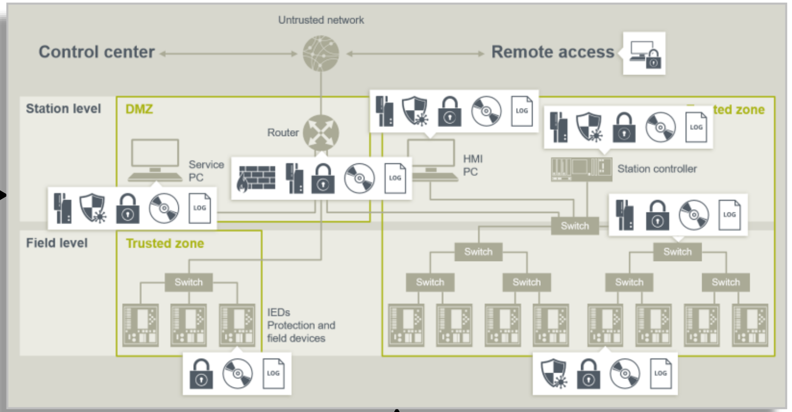
IEC 62443-3-3 **IEC 62351**

Product Supplier — IT Infrastructure

IEC 62443-3-3 **IEC 62443-4-2** **IEC 62443-4-1**

IEC 62351

OT - Infrastructure



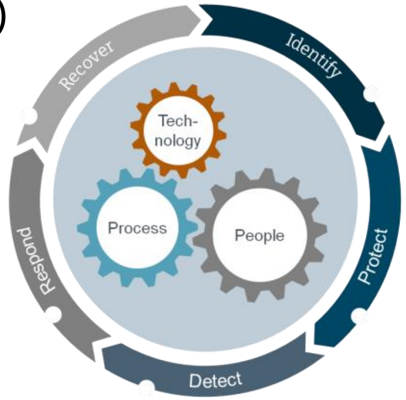
Procedural: e.g.: ISMS for operator, or requirements for the development process for integrators and manufacturers

Functional: e.g., security levels, strength of security measures

Technical: e.g., security measures implementation, support interoperability

Conclusions

- Machine-2-Machine connectivity down to field devices is a major driver for the Digital Grid
- The threat level for critical infrastructures like the Digital Grid is rising and requires appropriate means
- Cyber security has been acknowledged as prerequisite for limiting risks in and to support a reliable Digital Grid
- Standardization and guideline activities support the alignment of approaches and supports interoperability
- Regulation fosters adoption of security by domain specific requirements (e.g., German IT-Security Law)
- Security-by-Design is essential to provide appropriate security features from the ground
- Cyber security needs a holistic approach – collaboration between vendors, integrators and operators; taking into account people, processes, and products in the specific domain
- Still, some challenges remain, like the migration from existing more closed environment to an open environment featuring appropriate cyber security measures



Energy Data and Adaptive Consumption

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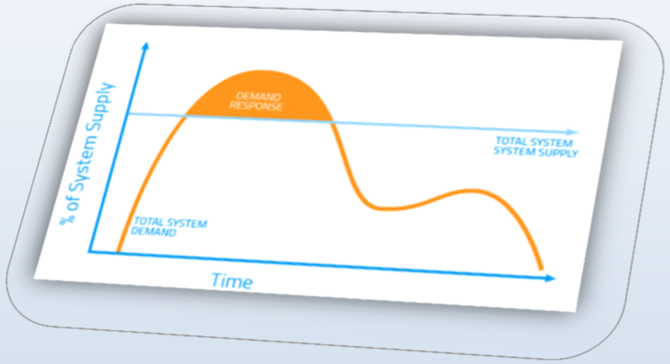
IARIA

CAL STATE LA
CALIFORNIA STATE UNIVERSITY, LOS ANGELES

About Vivian Sultan, PhD

Professor of Information Systems and Business Management at California State University (CSULA). Dr. Sultan holds a PhD in Information Systems and Technology from Claremont Graduate University. She is a certified professional in Supply Management with experience in account product management, operations, and automated system projects development. Prior to her current role, Dr. Sultan served as a Senior Analyst at Edison Materials Supply, an Account Product Manager at the Walt Disney Studios. Her publications and research focus on energy informatics and the digital transformation within supply chains.

Energy Data and Adaptive Consumption For Grid Reliability



Grid reliability is the greatest concern resulting from the current challenges facing electric utilities. The argument is that Energy Data and Adaptive Consumption will play a significant role in meeting challenges facing electric utilities by allowing high value services, such as geographically-targeted demand reductions, load building, and system balancing.

Adaptive consumption and load flexibility are emerging as the new powerful iteration of Demand Response that will reduce system costs, facilitate grid modernization, and provide environmental benefits. The United States of America show nearly 200 GW of cost-effective load potential, based on recent studies, and the national benefits of load flexibility could exceed $15 billion/year by 2030. Unleashing that potential will be the job of regulators and utilities to offer supporting policies, technology standards, regulatory incentives and the analytical method to facilitate the transition.

Smart Grid Reliability

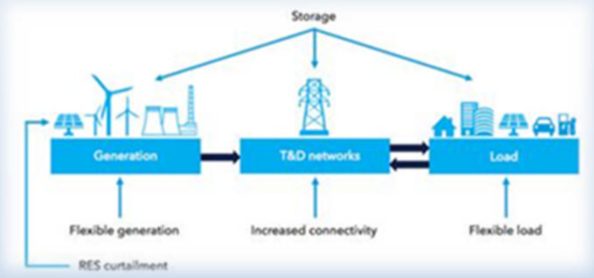
Smart Grid: a new class of technology to bring the electricity delivery system into the 21st century - Network technologies are the backbone of this system

- ✓ Must be adaptable, strong and responsive
- ✓ $338–$476 billion in the next twenty years to incorporate in DERs, intelligence technologies, advanced systems, and applications
- ✓ Tools for optimizing grid operations and to forecast future problems are crucial within the modern grid design

Reliability: the degree to which the performances of the elements of the electric system result in power being delivered to consumers within accepted standards and in the amount desired - Measured by outage indices

Load Flexibility

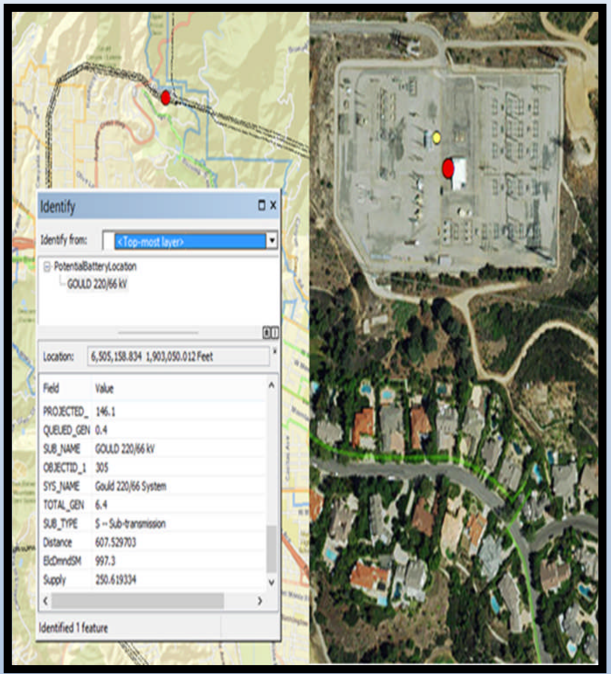
Load can be managed to address new challenges of an evolving power system
- ✓ Geographically-targeted demand reductions
- ✓ Load building
- ✓ System balancing



New methods for quantifying load flexibility value
- ✓ Determining location-specific value of distributed resources
- ✓ New emerging programs enabled by smart thermostats and Auto-DR-gateways to accessing electrified building load
- ✓ Quantified value and associated market potential are derived from reductions in system peak demand

Supporting policies, creative planning, technology standards, regulatory incentives to unlock load flexibility benefits

Location-Specific Value of Distributed Resources
A New Method for Quantifying Load Flexibility Value


Identify

Identify from: <Top-most layer>

PotentialBatteryLocation
GOULD 220/66 kV

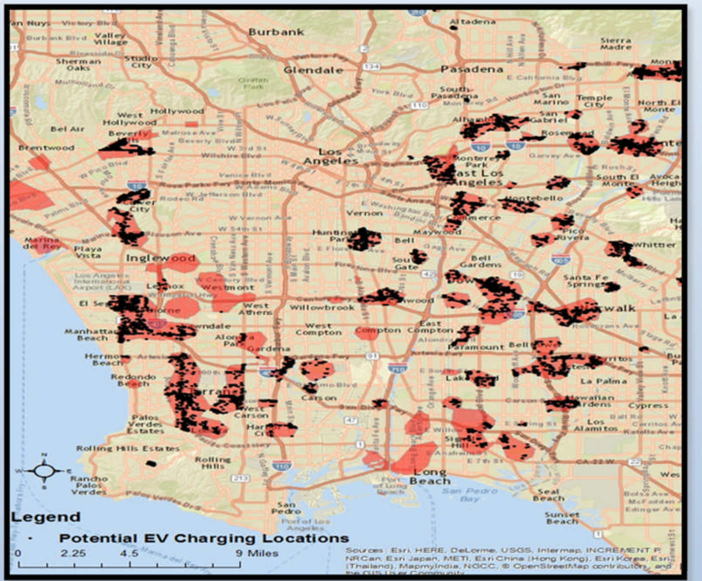
Location: 6,505,158.834 1,903,050.012 Feet

Field	Value
PROJECTED_	146.1
QUEUED_GEN	0.4
SUB_NAME	GOULD 220/66 kV
OBJECTID_1	305
SYS_NAME	Gould 220/66 System
TOTAL_GEN	6.4
SUB_TYPE	S -- Sub-transmission
Distance	607.529703
ElcDmndSM	997.3
Supply	250.619334

Identified 1 feature

$$E = A * r * H * PR$$

E = DER's total energy output
A = Total solar panel Area
r = solar panel yield
H = Annual average solar radiation on tilted panels
PR = Performance ratio



Maximum Remaining Generation Capacity = Current Capacity Load - (Solar Potential + Existing Generation)

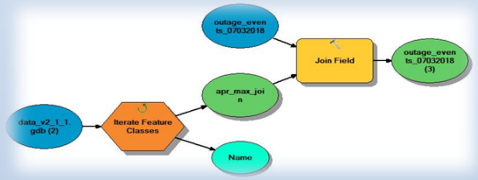
Visions For Grid Reliability

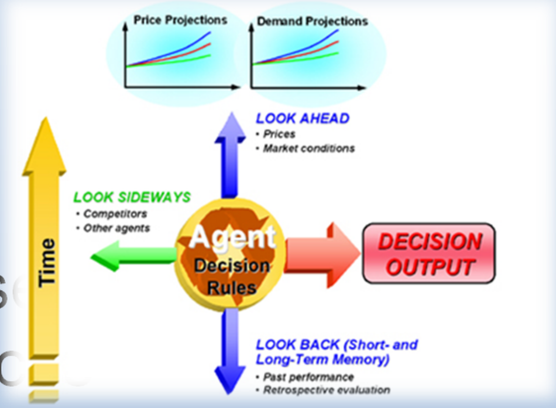
- ✓ Consumers to play a significant role in the operation of the electric grid by reducing or shifting their electricity usage during peak periods
- ✓ Smart grid technologies, distribution system modeling and analysis, transactive energy, and consumer behavior modeling to dynamically optimize grid operations
- ✓ Load Flexibility provides the grid operators with resource options for balancing supply and demand
  - ❑ A win for all
    - ▪ For the utility by ensuring adequate electricity supply and grid reliability
    - ▪ For the customer through new DR-enabled revenue streams
    - ▪ For the environment by reducing energy consumption and the associated need for new carbon-intensive power generation facilities

Energy Data and Adaptive Consumption

Modeling to quantify the relationship between load flexibility potential / incremental value and DR resource additions

- ✓ Accounting for Operational constraints
- ✓ Assessment of incremental value, frequency regulation, and other system-wide benefits of peak demand reduction
- ✓ Converting value to hourly price series
- ✓ Dynamic pricing (all customer segments)

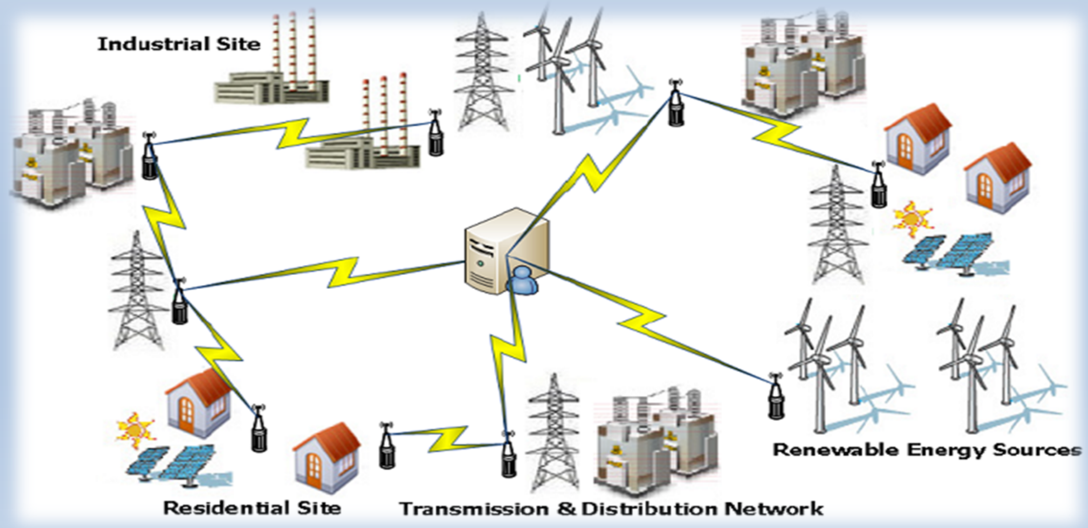




Utilization algorithms to dispatch DR resource based on price s

- ✓ Adoption of EVs, smart thermostats and other smart applianc
- ✓ Greater incentive for customer participation
- ✓ Potential increase over existing DR capability
- ✓ New customer engagement initiatives and advanced portfolio dispatch strategies

Together…. Shaping the Future of Electricity



Adaptive Consumption: The Flexibility is in the Grid

ENERGY 2020 Panel

Eric MSP Veith <eric.veith@offis.de>

In a Nutshell

Panelist’s Elevator Pitch

Electric Power is a When-You-Need-It Ressource

- It should be – often is not
- Problems can be visible (cf. California‘s planned blackouts) or invisible (ask any operator)
- Should we change customer behavior? No: It might be easy, but does not pay off on a civilisatory scale

No need to wait for Nuclear Fusion: Your Flexibility is in the grid

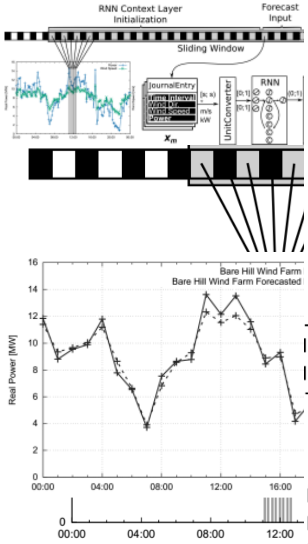
- Decentralized optimization with grid in mind
- Multi-usecase at customer sites
- Only possible with AI: Forecasting, Multi-Agent Systems, even Deep Refinforcement Learning

Some examples follow.

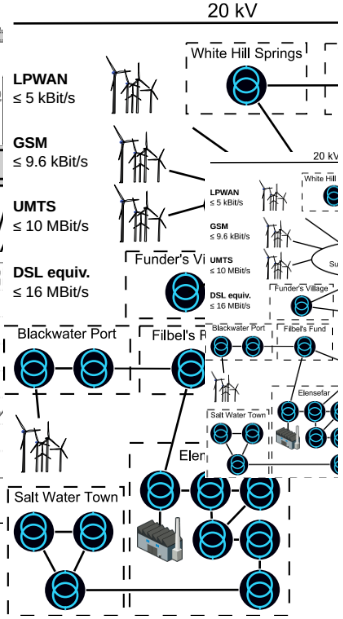
Multi-Agent Power Grid Operations

Universal Smart Grid Agent for Distributed Power Generation Management

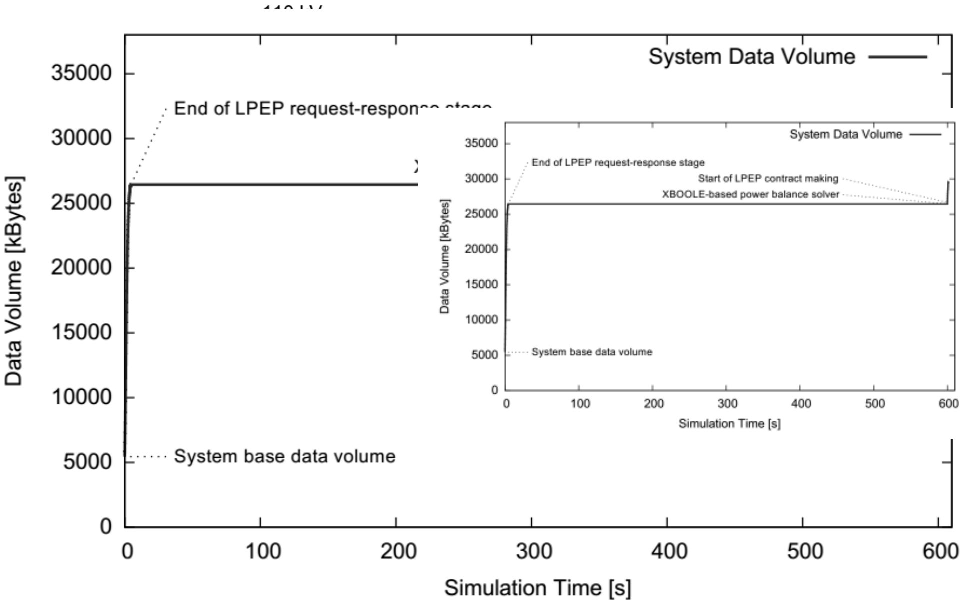
Vorhersage



Kooperation



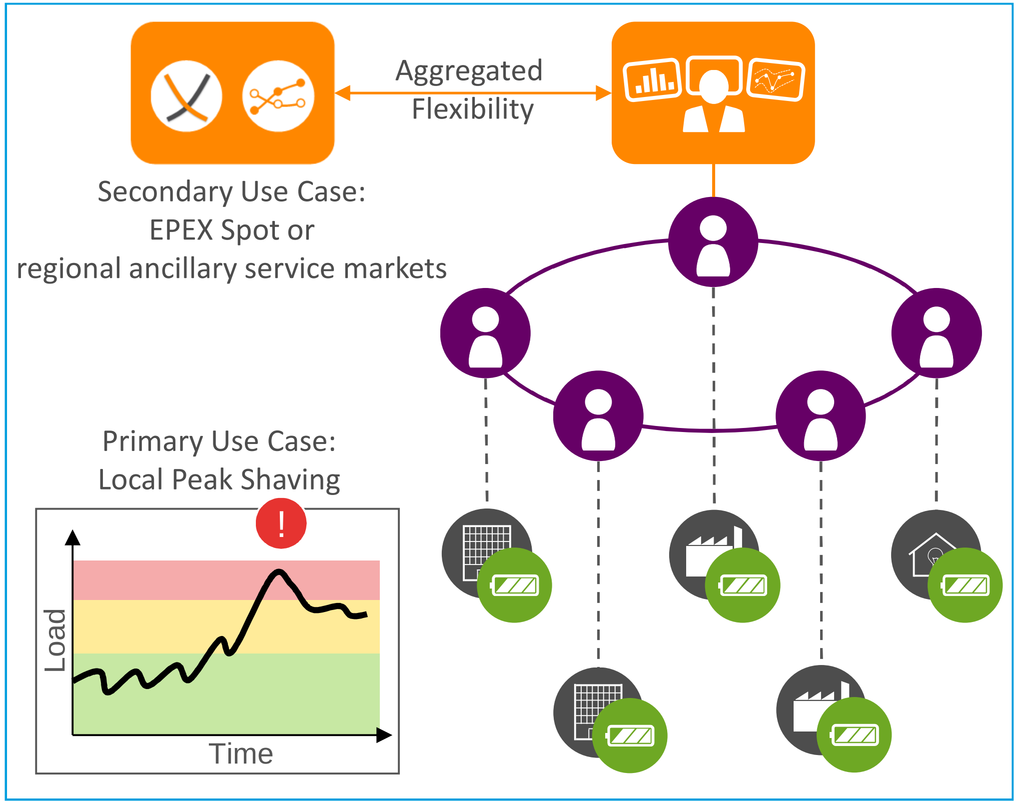
Equilibrium



Line loss reduced by **17MW** in Fukui-TEPCO Tokyo Subgrid Benchmark ($\xi = 0{,}6\,^{W}{}_{B}$)

Multi-Purpose Battery Swarm

Kooperationsprojekt mit der be.storaged GmbH



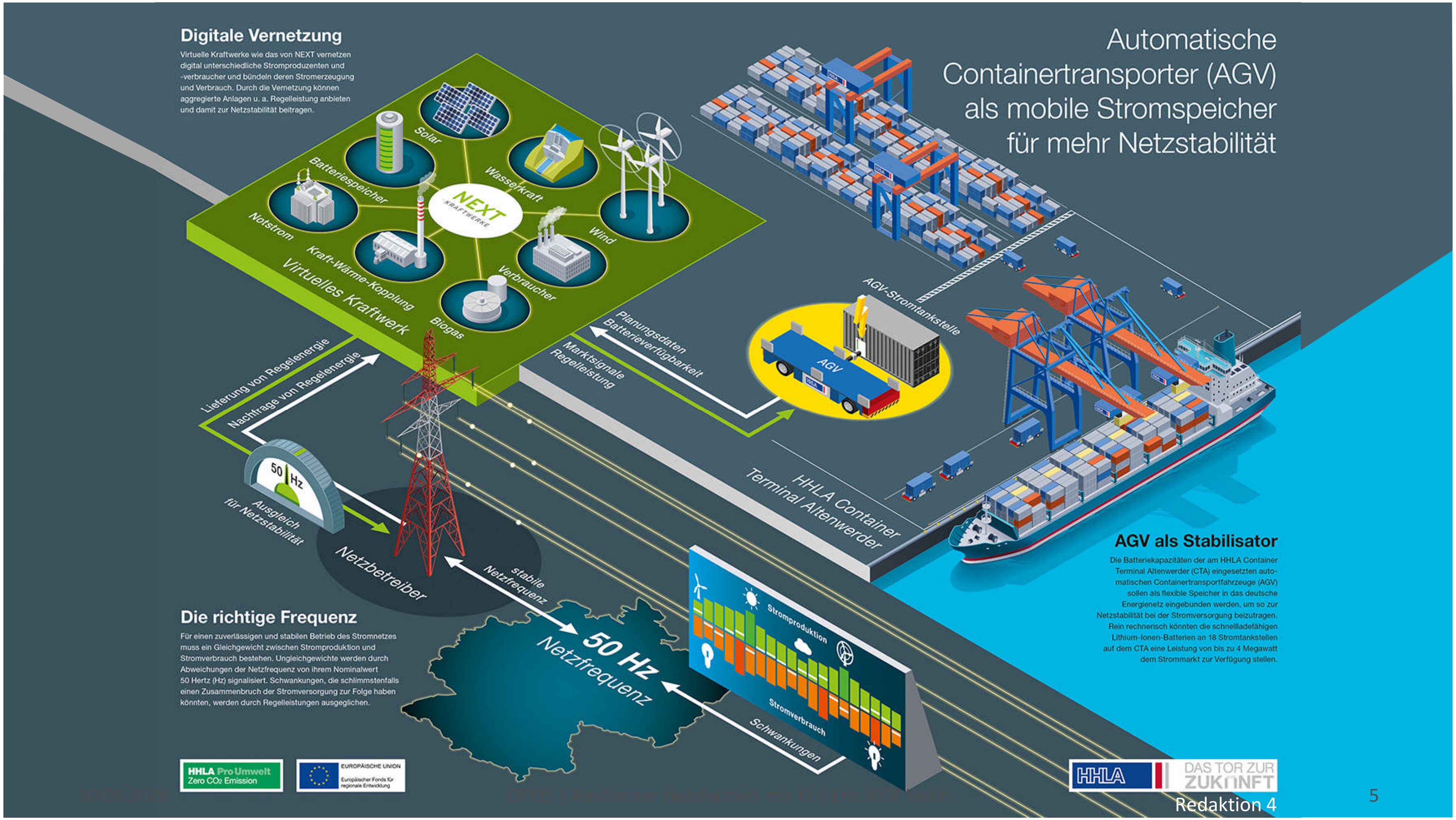
Battery Swarms offer lexibility

- Primary: Peak load management for enterprises & industry
- Still flexibilities left: provide ancillary services

Decentralized Battery Swarm

- Intelligent, autonomous agents
- Fast and robust optimization with guarantees

In field test



Automatische Containertransporter (AGV) als mobile Stromspeicher für mehr Netzstabilität

Digitale Vernetzung

Virtuelle Kraftwerke wie das von NEXT vernetzen digital unterschiedliche Stromproduzenten und -verbraucher und bündeln deren Stromerzeugung und Verbrauch. Durch die Vernetzung können aggregierte Anlagen u. a. Regelleistung anbieten und damit zur Netzstabilität beitragen.

Die richtige Frequenz

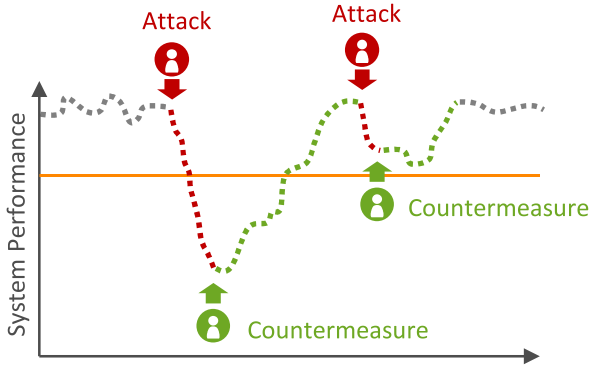
Für einen zuverlässigen und stabilen Betrieb des Stromnetzes muss ein Gleichgewicht zwischen Stromproduktion und Stromverbrauch bestehen. Ungleichgewichte werden durch Abweichungen der Netzfrequenz von ihrem Nominalwert 50 Hertz (Hz) signalisiert. Schwankungen, die schlimmstenfalls einen Zusammenbruch der Stromversorgung zur Folge haben könnten, werden durch Regelleistungen ausgeglichen.

AGV als Stabilisator

Die Batteriekapazitäten der am HHLA Container Terminal Altenwerder (CTA) eingesetzten automatischen Containertransportfahrzeuge (AGV) sollen als flexible Speicher in das deutsche Energienetz eingebunden werden, um so zur Netzstabilität bei der Stromversorgung beizutragen. Rein rechnerisch könnten die schnellladefähigen Lithium-Ionen-Batterien an 18 Stromtankstellen auf dem CTA eine Leistung von bis zu 4 Megawatt dem Strommarkt zur Verfügung stellen.

Adversarial Resilience Learning

Fully self-adaptive Agents analyze & learn Resilient Operation of the Power Grid



Two Agents Compete for Control of a Power Grid

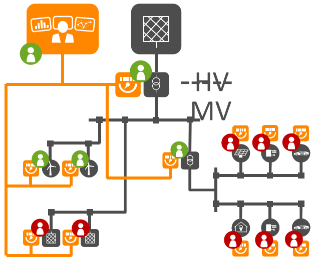
- Self-learning, self-adaptive software agents
- Analyzer and Operator Agent compete for control, thereby training themselves
- No domain-knowledge: AI-based modelling of unknown systems

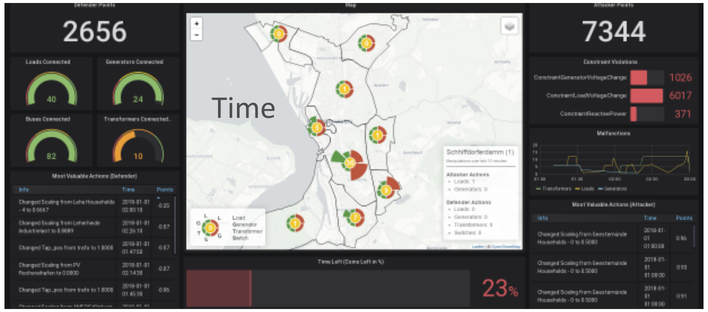
Preliminary Work

- PYRATE: Polymorphic agents as cross-sectional software technology for the analysis of the operational safety of cyber-physical systems

Faster Learning & Better Strategies: Many Opportunitinies

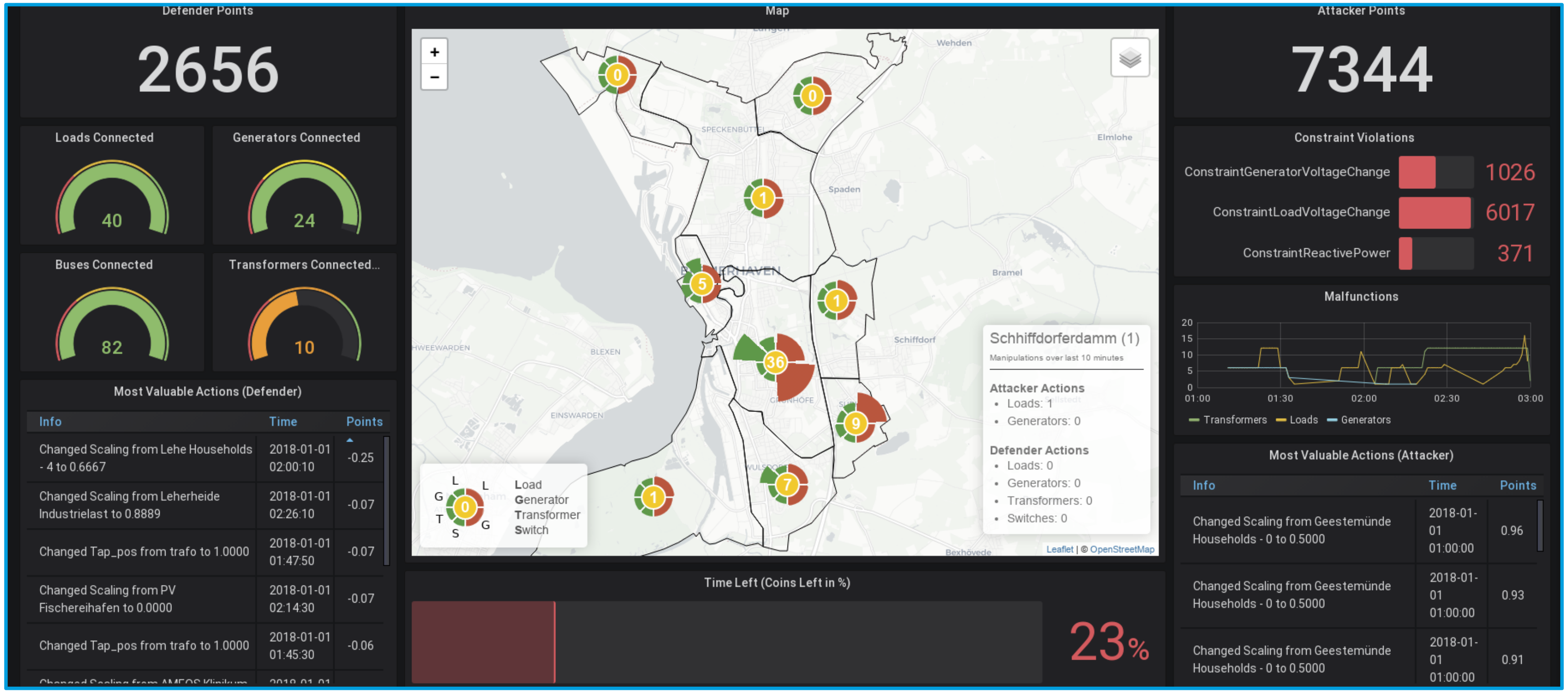
- Self-adaptive grid control
- Offer real resilience
- CO_2 reduction strategies
- Strategic grid planning





Power Grid Immune System

Flexibility comes from grid control, not from changing user behavior



Schhiffdorferdamm (1)

Manipulations over last 10 minutes

Attacker Actions
- Loads: 1
- Generators: 0

Defender Actions
- Loads: 0
- Generators: 0
- Transformers: 0
- Switches: 0

Constraint Violations

ConstraintGeneratorVoltageChange	1026
ConstraintLoadVoltageChange	6017
ConstraintReactivePower	371

Most Valuable Actions (Defender)

Info	Time	Points
Changed Scaling from Lehe Households - 4 to 0.6667	2018-01-01 02:00:10	-0.25
Changed Scaling from Leherheide Industrielast to 0.8889	2018-01-01 02:26:10	-0.07
Changed Tap_pos from trafo to 1.0000	2018-01-01 01:47:50	-0.07
Changed Scaling from PV Fischereihafen to 0.0000	2018-01-01 02:14:30	-0.07
Changed Tap_pos from trafo to 1.0000	2018-01-01 01:45:30	-0.06
Changed Scaling from AMEOS Klinikum	2018-01-01	

Most Valuable Actions (Attacker)

Info	Time	Points
Changed Scaling from Geestemünde Households - 0 to 0.5000	2018-01-01 01:00:00	0.96
Changed Scaling from Geestemünde Households - 0 to 0.5000	2018-01-01 01:00:00	0.93
Changed Scaling from Geestemünde Households - 0 to 0.5000	2018-01-01 01:00:00	0.91

Community Energy Systems: Extending the Community

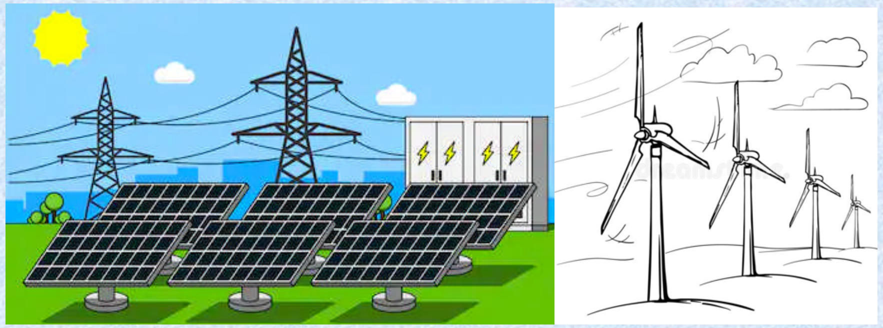
Local Industry

People

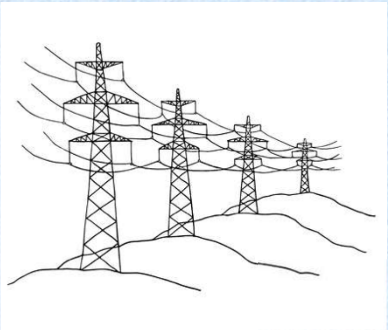
Transport

Housing

Community



Local Renewable Generation



Grid Capacity

Local Storage

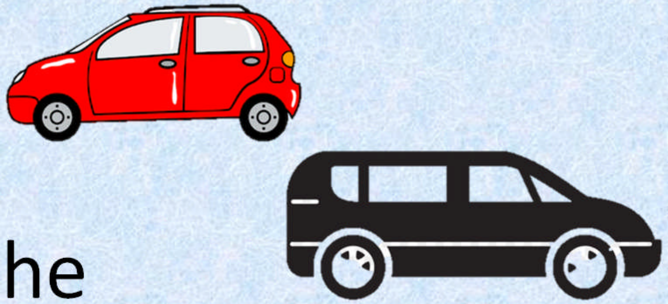
Understanding the Industry Load

1. Can it be electrified?
2. What are the demands; time profile?
3. Is there flexibility, particularly in timing?
4. Is there storage potential in the process/industry itself?

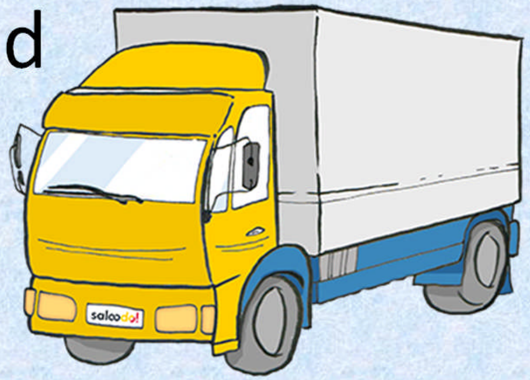
Understanding the Community/Industry Relationship

1. What are the implications of the factory workers being a part of the community?
2. Does this have the potential to impact the electricity demand profile for the community as a whole (eg working hours, shift work)?
3. Is there potential for the industry to provide resources back to the community (eg heat)?

Transport Electrification

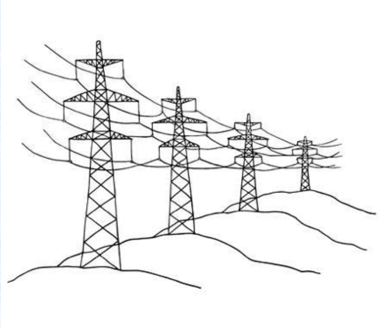


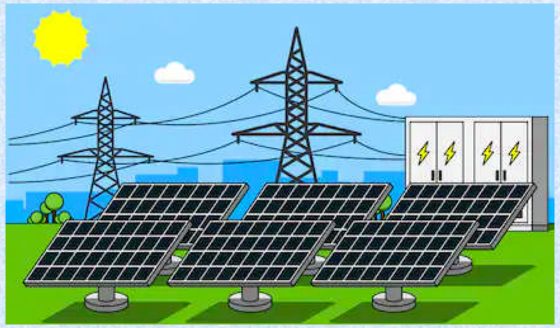
1. Most LPVs are likely to be ”contained” within the extended community, facilitating direct solar PV charging.
2. What is the potential for industry-related goods transport to be included as a part of the community electricity generation/storage/demand profile?



Local Grid Capacity, and Generation and Storage Potential

1. Can the grid infrastructure cope with increased electrification?
2. What is the potential for locally generated renewable electricity?
3. What is the potential for local storage; for local community-side load management?
4. What opportunities for improved efficiency? Local direct DC distribution?





Smart, Adaptable, Energy Flow/Balance Management

1. Need reliable smart control to manage local micro-grid.
2. Are there issues with local grid stability, and how are they dealt with?
3. Software needs to be adaptable, as environment will be constantly changing and developing.

A Practical Approach to Data Collection and Observability Analysis in Distribution Networks

Michael Negnevitsky

ENERGY 2020
September 27 - October 01, 2020
Lisbon, Portugal

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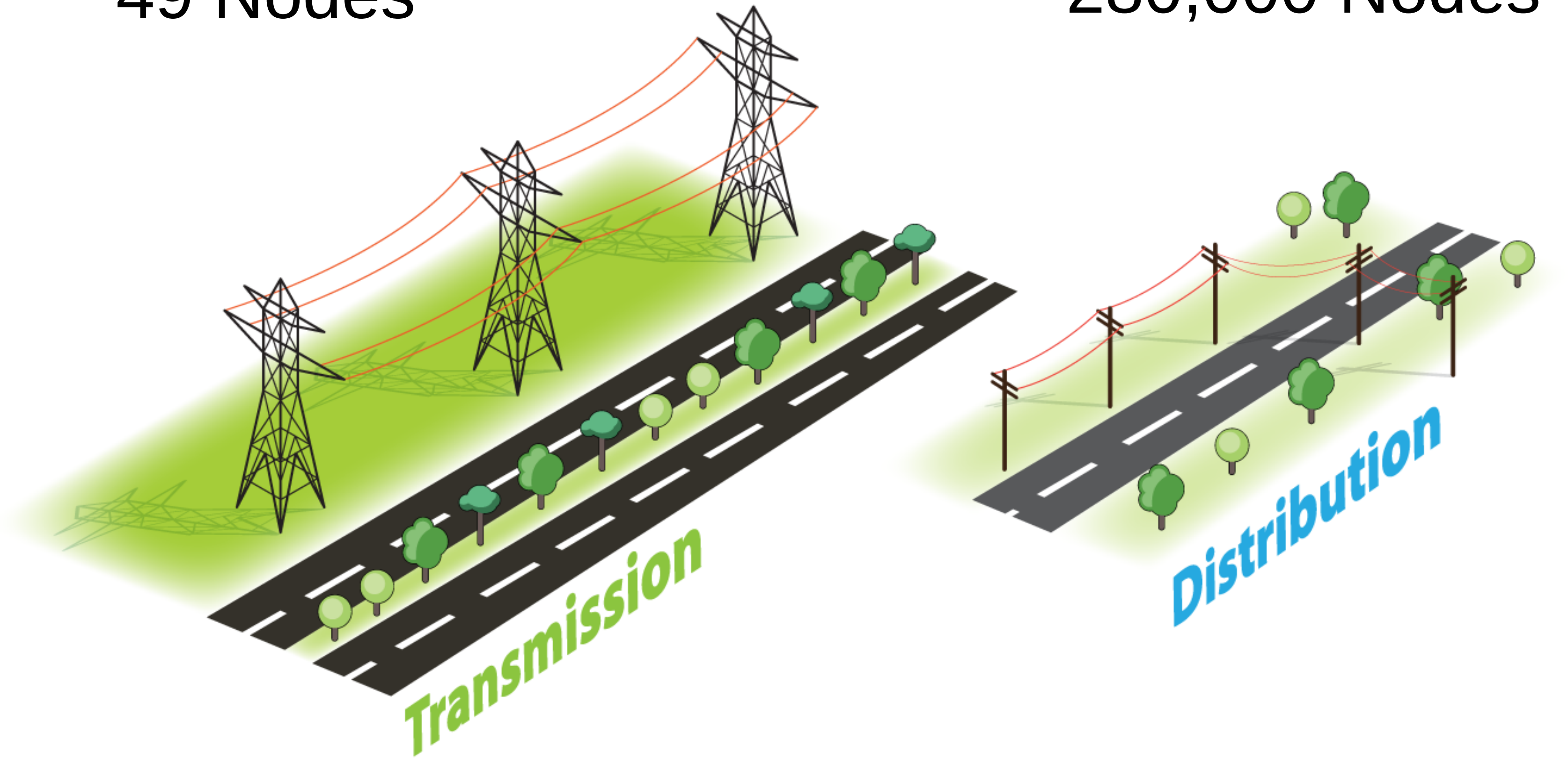
Introduction

- The state of an electrical network is defined by the voltage magnitude and angle at every bus in the network.
- Traditionally state estimation is applied to transmission networks, where numerous real-time measurements are available. In distribution networks, however, the number of available real-time measurements is usually very limited.

Tasmanian Network Size

49 Nodes

280,000 Nodes



Introduction (cont.)

- Pseudo-measurements are often used – large margins of error. The estimated state is uncertain.
- Current SE methods aim at estimating the exact value of the network parameters. However, due to the high level of uncertainty in distribution networks, the estimated network state can be significantly different from the real network state.
- Without information about the SE accuracy, no objective assessment of the network state can be made.

Introduction (cont.)

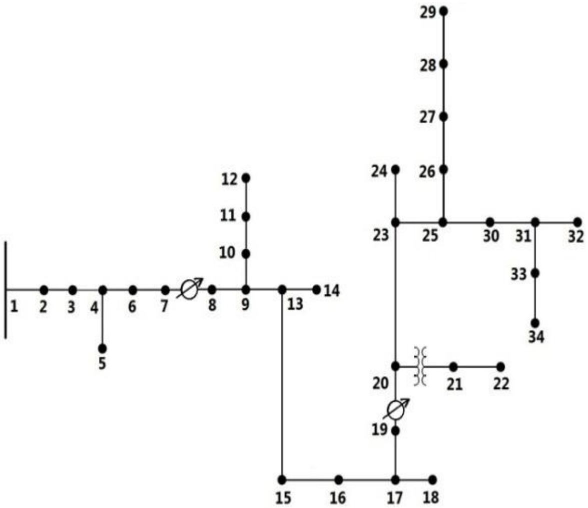
- The fact that the principal concern of the network operator is to keep the network within its constraints.
- The constraints of a network are defined by its physical properties (e.g. thermal limits of network components) and regulations (e.g. the voltage compliance range).
- The proposed approach on providing the confidence that the estimated parameters are within their respective constraints.
- The confidence value takes into account both the accuracy of the SE and the proximity of the result to its constraints.
- This provides practical information for the distribution network operator even in presence of uncertain SE inputs.

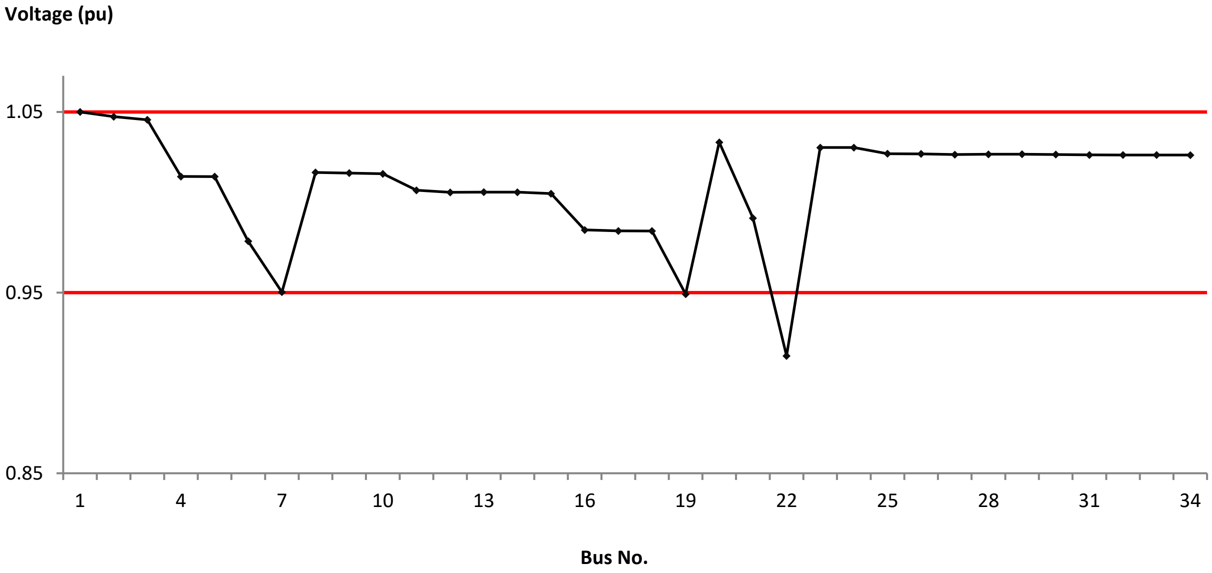
Calculating confidence values

Instead of attempting to estimate the exact value of the estimated parameters, **the proposed approach calculates the confidence that these parameters are within their constraints**.

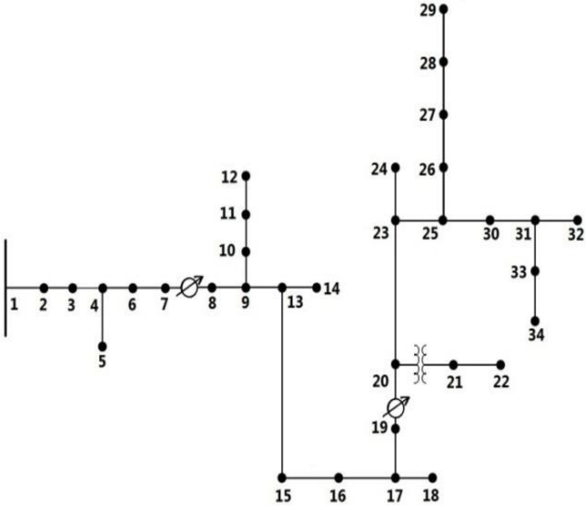
This effectively combines both the accuracy of an estimation and its proximity to the constraint into a single number.

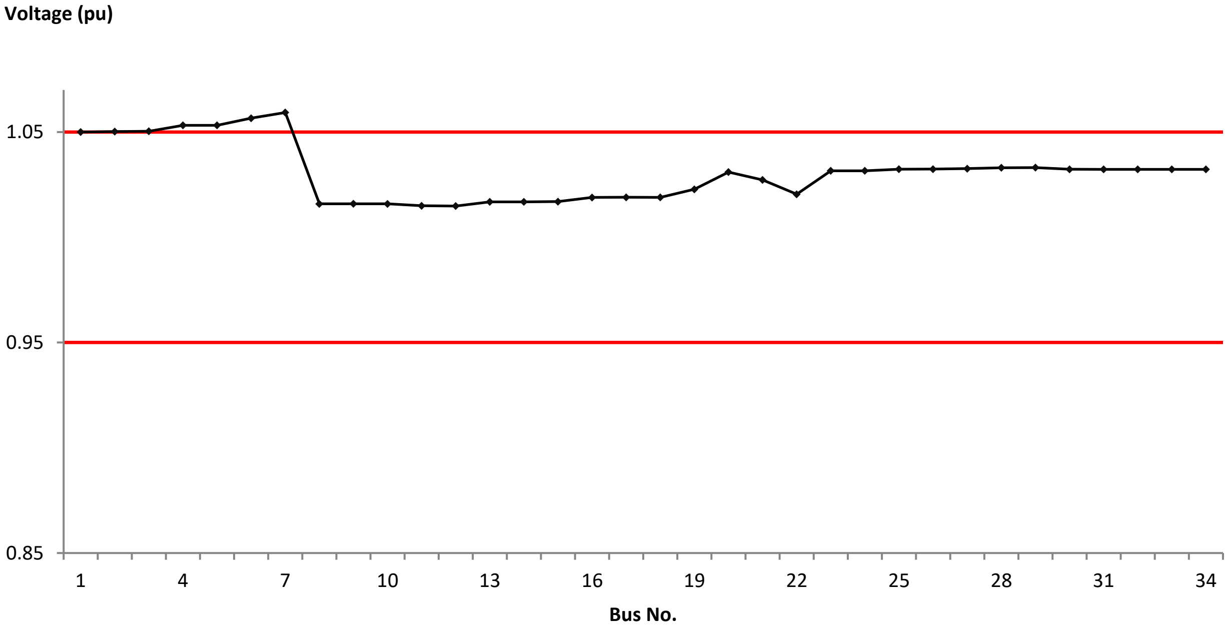
Voltage profile under the base loading condition without distributed generation (base load) – traditional approach





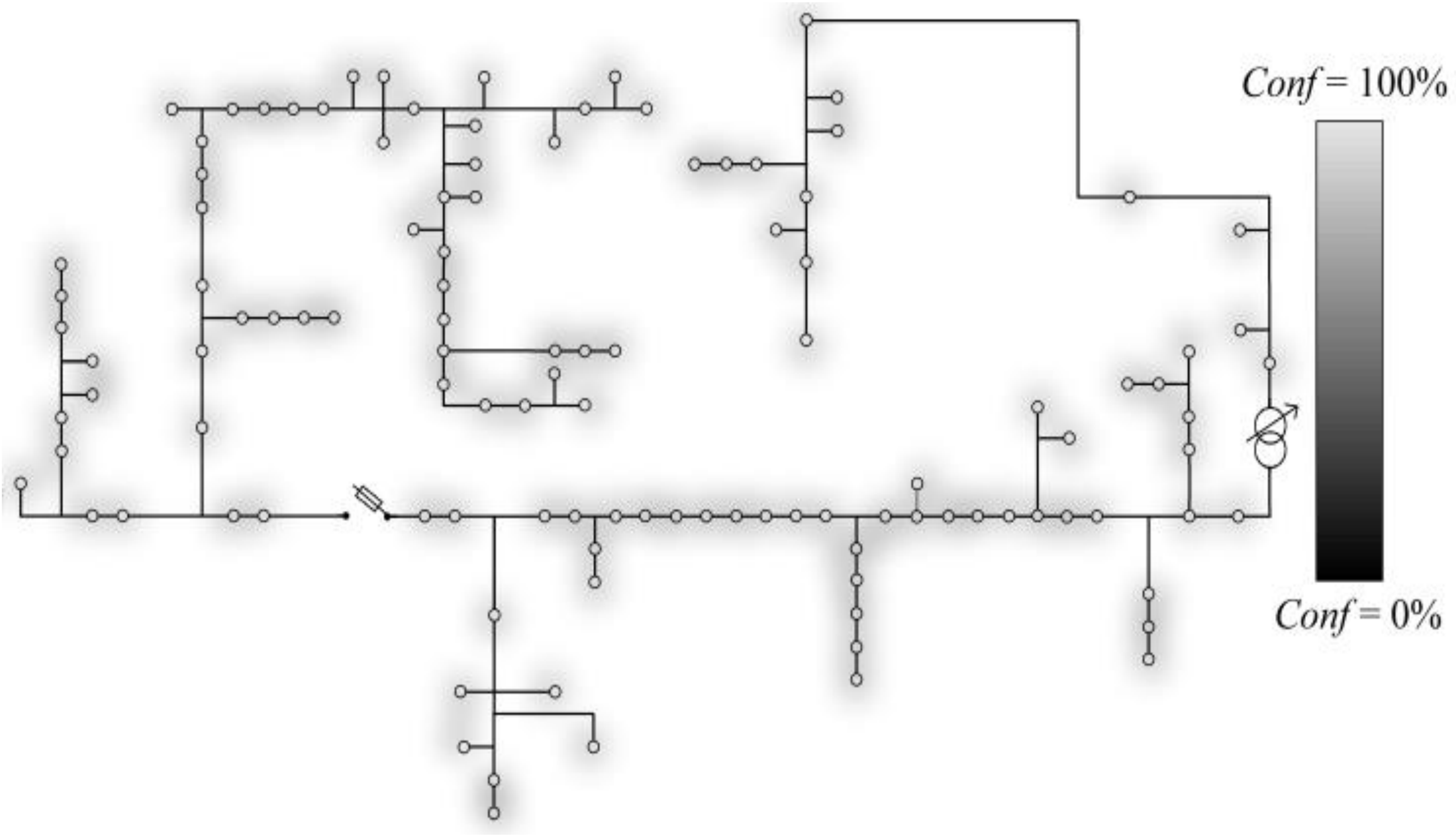
Voltage profile under the low loading condition with distributed generation – traditional approach





- The confidence that a particular parameter is within its constraints can be low due to either a **low accuracy of the estimate, or the proximity of the parameter estimate to its constraints**.
- The conventional SE approach only provides the proximity of the parameter estimates to their constraints.
- The proposed approach to SE takes the accuracy of the parameter estimate into account.
- This allows the distribution network operator to make informed decisions on the network operation, even if a large amount of uncertainty is present in the SE result.

Estimated voltage profile for the 145-bus feeder: heat map overlay



Improving Energy Efficiency in High Performance Computing by Powering Down Unused Resources

ENERGY 2020: Panel on Energy Data and Adaptive Consumption

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2020-09-28 – 2020-10-01

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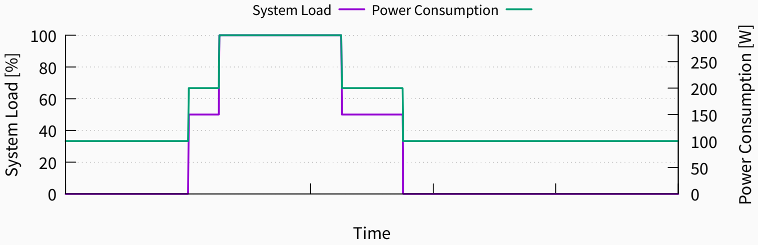
Introduction

- Scientific applications and experiments become ever more complex
  - Faster and bigger supercomputers are required for computation and storage
  - Up to 10,000,000 processor cores and up to 30 MW of power
- Supercomputers are often operated without much concern for energy consumption
  - Compute and storage nodes run 24/7 even if no jobs are running
  - Usually not a problem for larger systems since utilization is close to 100 %
- Especially smaller research clusters have idle times
  - CPUs feature some energy saving features, nodes still run 24/7

Introduction…

- Running 24/7 offers best performance and predictable energy consumption
  - Can be a huge waste of energy depending on idle times



- Several ways to reduce energy consumption come to mind
  - Reduce the energy required at runtime (see final slide)
  - Power down unused resources, including nodes

Approach

- Supercomputers typically use batch scheduling software
    - Jobs are executed whenever resources are available
    - Alternatively, users can wait for interactive sessions
- Batch schedulers have a complete picture of pending jobs
    - Can take decisions to shut down nodes if they are not required in the near future
- Shutting down nodes has to be fine-tuned to prevent decreasing performance
    - Jobs waiting for nodes to be powered up cannot do their work

Approach…

- SLURM is widely used and supports suspending and resuming nodes
  - Suspending and resuming can also be shutting down and powering up
  - Timeouts and exclusions can be configured for maximum flexibility

```
SuspendProgram=/etc/slurm/suspend.sh
ResumeProgram=/etc/slurm/resume.sh
SuspendRate=10
ResumeRate=10
SuspendTime=900
```

- This configuration suspends and resumes at most 10 nodes per minute
  - This prevents power surges by not resuming the whole cluster at once
  - Nodes are suspended if no jobs have been running for 15 minutes

Approach…

- Shutting down nodes is easy
  - Nodes are up and running and can be ssh'd into

```
for host in $hosts; do sudo /usr/bin/ssh $host poweroff; done
```

- Powering up nodes is slightly more difficult
  - Nodes are down and require support for powering on remotely (e. g., IPMI)

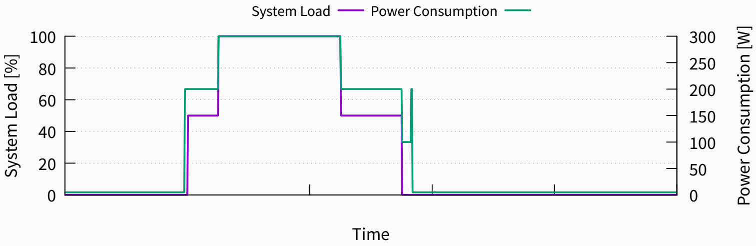
```
export IPMITOOL_PASSWORD='secret'
for host in $hosts; do ipmitool -I lanplus -H $host.ipmi -U ADMIN -E power on; done
```

Approach…

- `SuspendTime` is probably the most important parameter
  - If it is too low, nodes will shut down and power up all the time
  - If it is too high, energy savings will decrease
- Simplified example:
  - Idle: 100 W, shut down: 5 W
  - Shutting down: 1 minute at 200 W → 6 kJ extra
  - Powering up: 5 minutes at 200 W → 30 kJ extra
  - We need to save at least 36 kJ, that is, keep nodes off for at least 6.5 minutes

Approach…

- Same node and system load behavior as before
  - Node is mostly idle, one job does some setup, computation and cleanup



- Node is powered on when job is scheduled and shut down 15 minutes after its end
  - Power consumption spikes to 200 W but only for a short period of time

Conclusion

- There is still a lot of room for improvement
    - Shutting down and powering up servers takes a long time
        - It might also have a negative effect on the hardware's lifetime
    - Servers could be suspended and resumed like laptops
        - Suspending would be worth it even for shorter idle durations
        - Servers often do not support suspend and resume like consumer hardware
- Potentials for saving energy should also be considered in HPC
    - This presentation should just serve as a simple example to show what is possible
    - We have presented two[1] solutions[2] at ENERGY 2020 to support energy efficiency in HPC

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[1] ArduPower v2: Open and Modular Power Measurement for HPC Components (Bremer, Kuhn, Heidari)

[2] Improving Energy Efficiency of Scientific Data Compression with Decision Trees (Kuhn, Plehn, Alforov)

Questions

Thank you for listening! If you have any questions, please send me an e-mail to
`michael.kuhn@ovgu.de`