

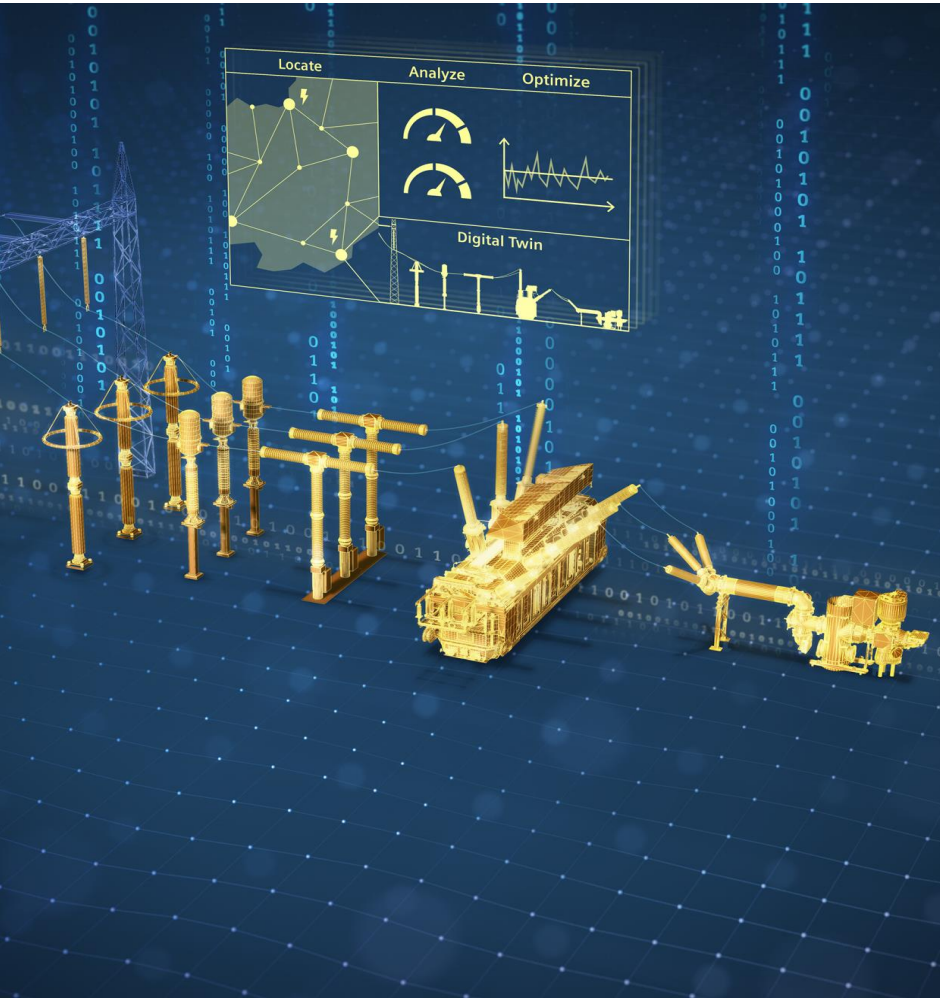
CONNECTING AN ALL-ELECTRIC WORLD

# Digizalized high-voltage products **Sensformer® and Sensgear® - Outlook**

Dr.-Ing. Dirk Helbig | Senior Principal High Voltage Products & Innovationmanager

# Digitalized Transmission Products: Sensformer® & Sensgear®

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1. Why?  
New requirements to Power Transmission and Distribution
2. What?  
Transmission Products -  
All products and systems for Power Transmission and Distribution
3. How?  
Sensformer® & Sensgear® -  
Intelligent combination of reliable transmission products combined with new opportunities of digitalization
4. Products, Sensors and Apps
5. Use cases



# Digitalization offers new opportunities to better manage current trends and challenges

## Trends

## Challenges

## Opportunities



# Expectations, requirements and challenges for Transmission and Distribution System Owners, Operators and business partners

## Total cost of ownership

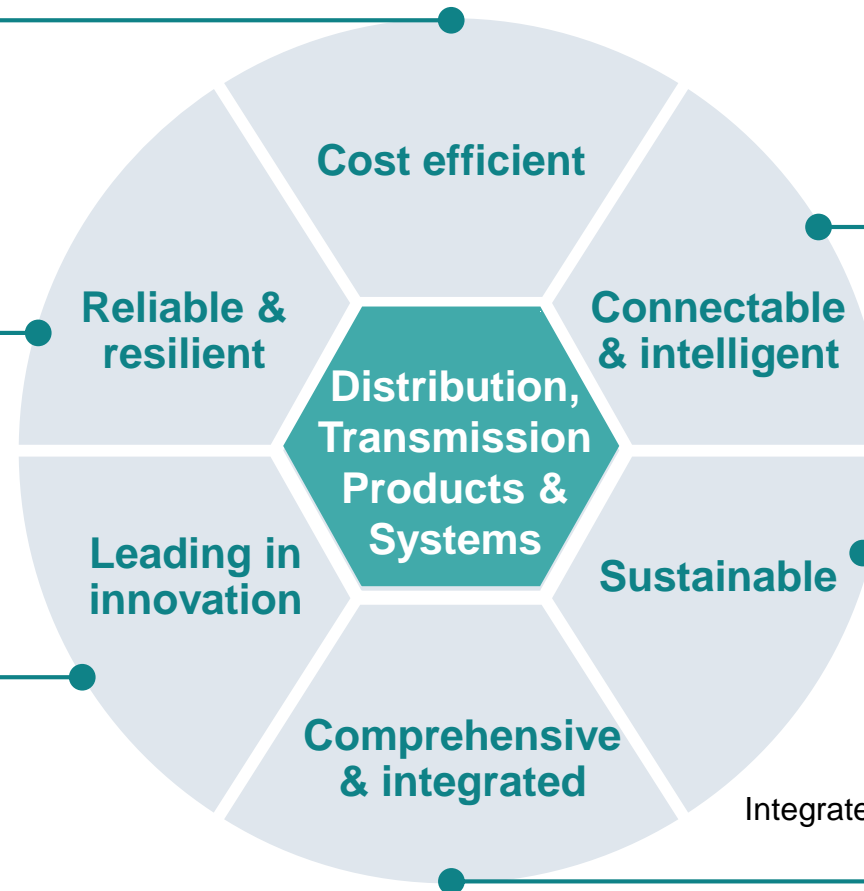
- Short delivery and commissioning times
- Highest overall value through predictable revenue stream and lowest costs of operation driven by energy efficient solutions

## Reliable & resilient

- Lowest failure rates
- Long product life times
- Global Resilience concept to Protect, Prevent and React

## Leading in innovation

- State-of-the-art technology
- Highest acceptance by end consumer
- Highest appreciation by society



## Connectable & intelligent

Digitalized products to optimize operations  
Secure data transmission  
Data storage on cloud solutions

## Sustainable

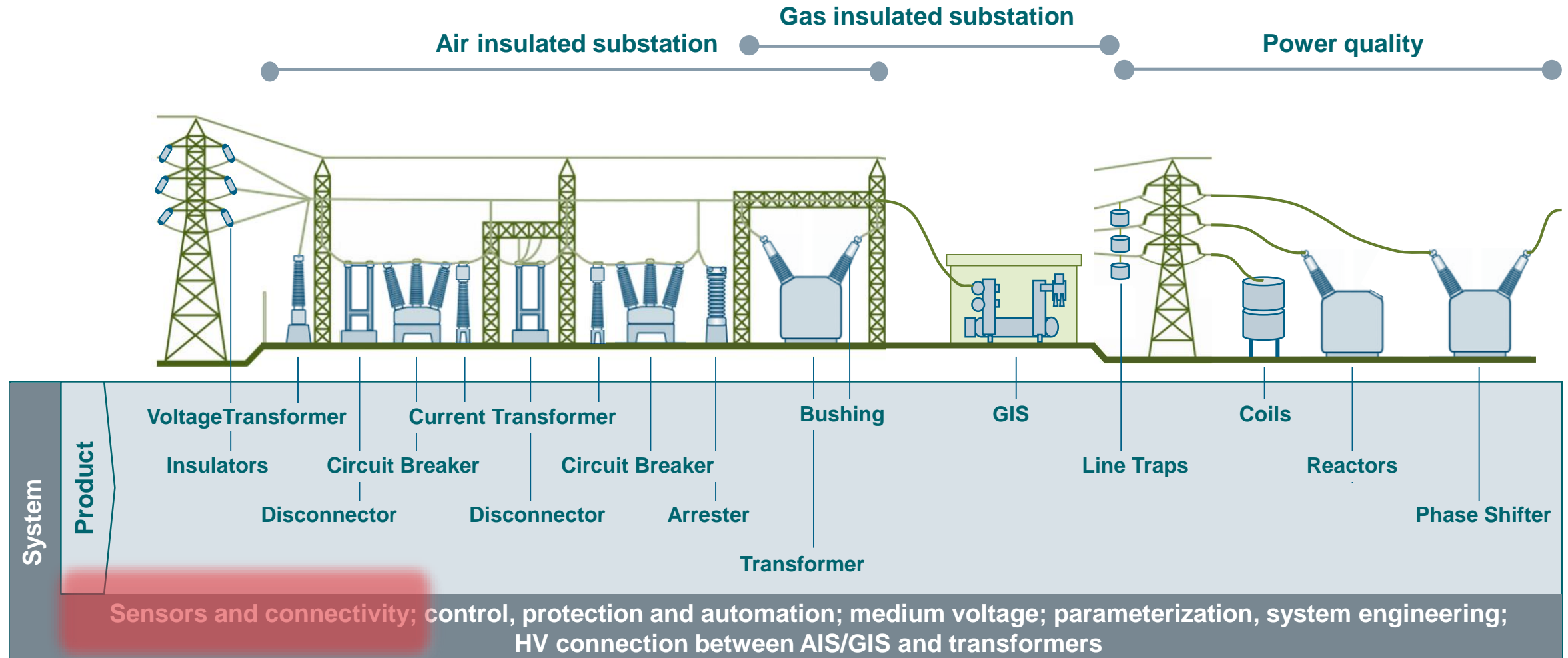
High efficiency products  
Minimal SF<sub>6</sub> volume and best in class leakage rate  
Blue products with no greenhouse gas impact  
Ester technology

## Comprehensive & integrated

Comprehensive ownership of products and systems  
Integrated in local, regional, national and international systems  
High flexibility and adaptability

# Transmission Products comprising all products of HV substations including their electrical integration to systems

**SIEMENS**  
*Ingenuity for life*

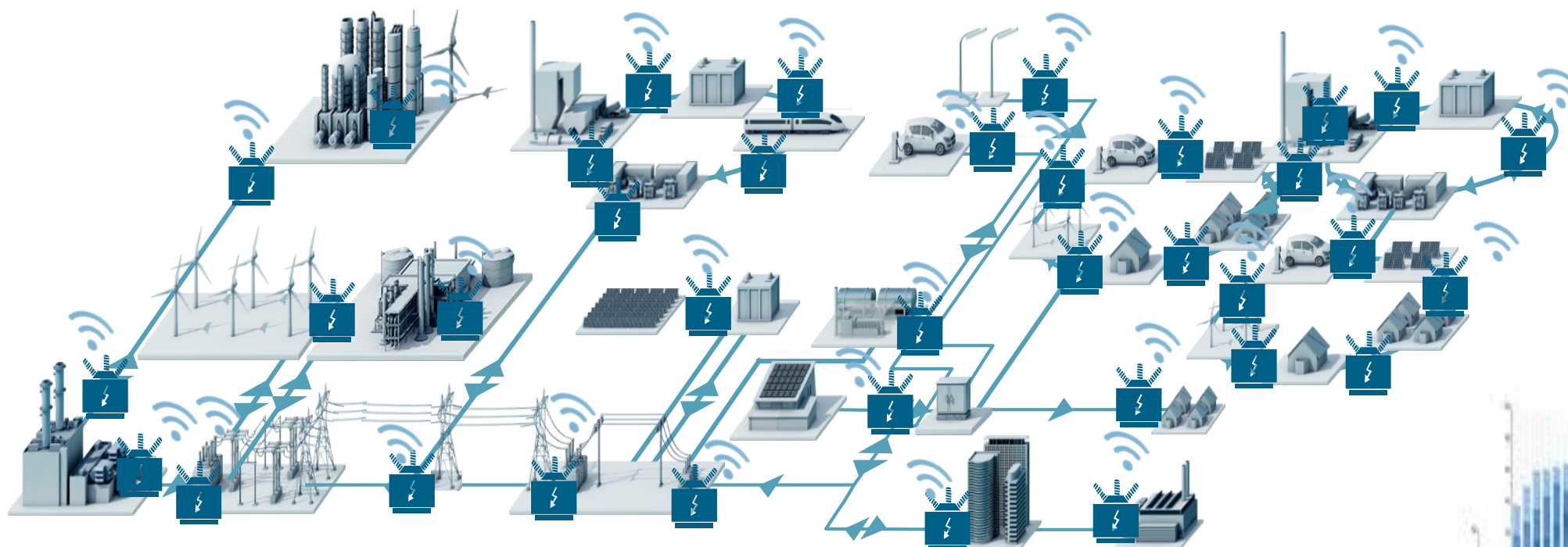


The journey  
started 2018



# Sensformer® enable our customers to get digitally connected

**SIEMENS**  
*Ingenuity for life*



**Transmission:**  
HV transmission

**Distribution:**  
Primary / Secondary

**Prosumer:**  
Supply & Consumption

Physics will always stay the same.

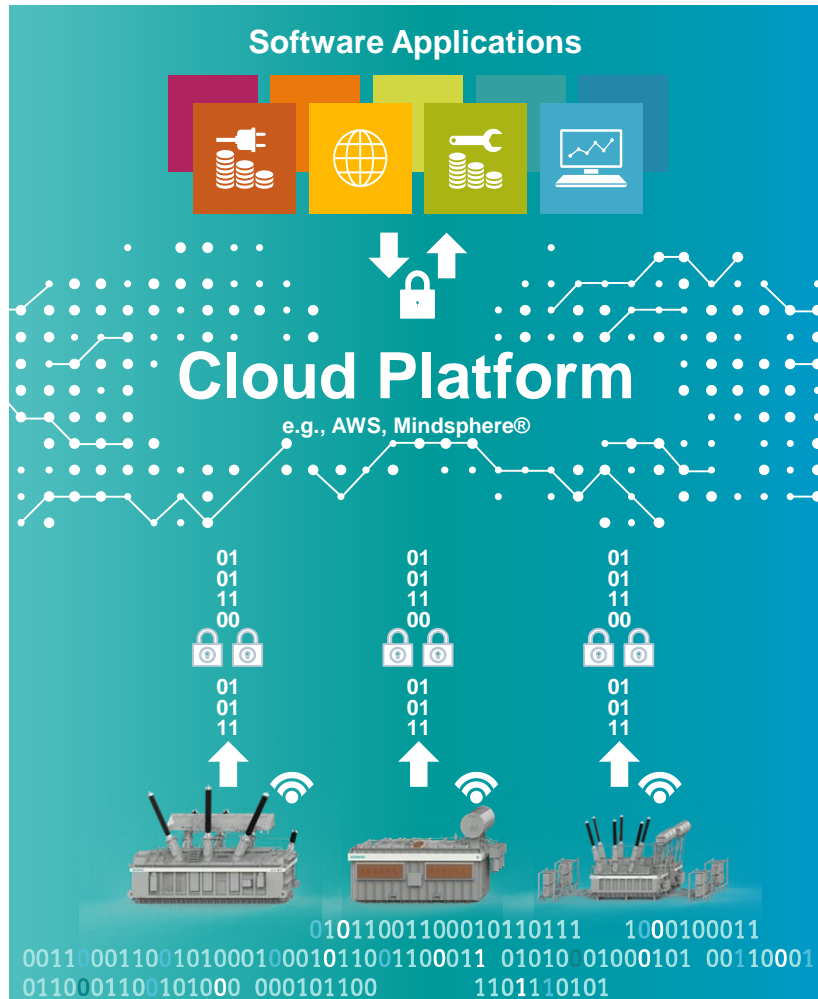
In the digital age it merges with information – creating benefits to manage changing power systems.

► **Therefore we started the journey from Transformers to Sensformer®**



# Sensformer® – Born Connected

## Transforming data into business value



- Sensformer® equipped to provide following direct measurements per default:
  - Oil Level Alarm
  - Top Oil Temperature
  - LV Winding Current
  - GPS Location
  - Local weather information
- Secure data transmission through GSM or Ethernet with state-of-the-art cyber security measures
- Data storage on cloud solution with graphic interface tool for data analysis
- Software applications for further value creation and operational enhancement



# Sensformer® App...

## Stay on-grid even when you're off-site



- Secure mobile connectivity
- Instant overview of asset status with real-time data
- Enhanced asset life cycle management
- Key KPIs at a glance
- Optional push messages in case of alarms



# Sensformer® reference China

## 110 kV / 40 MVA



- Equipped to provide following direct measurements:
  - Oil Level Alarm
  - Top Oil Temperature
  - LV Winding Current
  - GPS Location
  - Local weather information
- Secure data transmission through GSM or Ethernet with state-of-the art cyber security measures
- Data storage on cloud solution with graphic interface tool for data analysis
- Software applications for further value creation and operational enhancement

*“With this eco-friendly mobile substation Siemens Transmission Products is providing a solution that contributes to a stable and even more resilient grid in the Chinese market. It provides a maximum of operational safety and environmental friendliness and at the same time acts as an eye to the grid as it features a Sensformer®”*

*Dr. Beatrix Natter, CEO of Siemens Transmission Products.*

Unrestricted © Siemens 2019.

# The journey continues





# Extending the approach to entire Transmission Products family

**SIEMENS**  
*Ingenuity for life*

## Converting Transformer and Switchgear . . .

### Old:

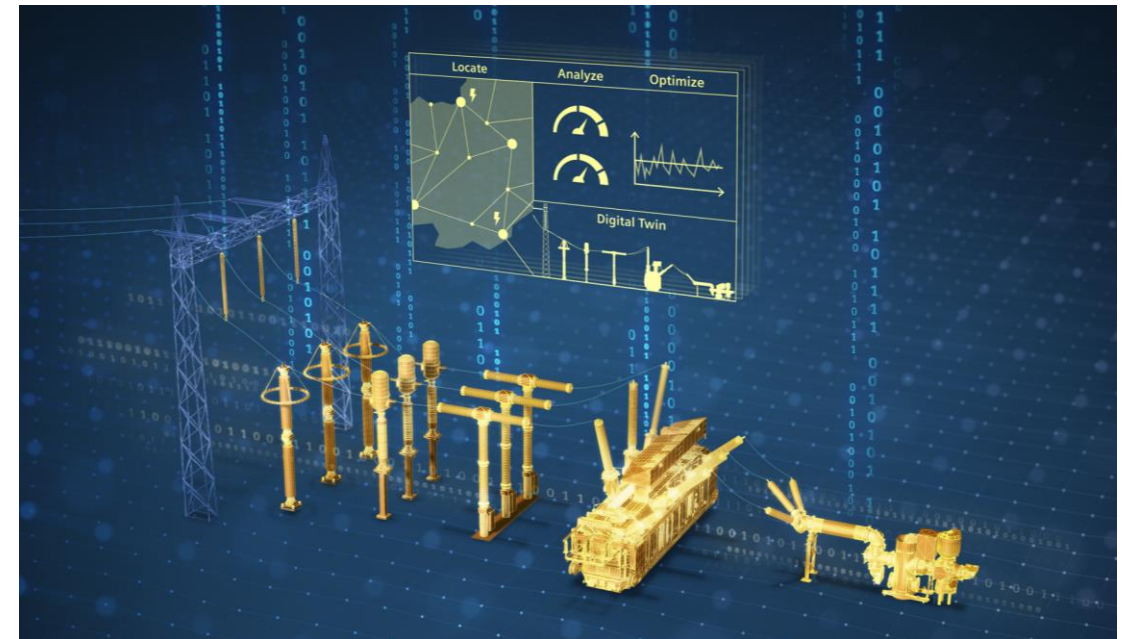
Voltage regulation, switching and measurement devices



## . . . into Sensformer® and Sensgear®

### New:

Merging reliable innovative hardware with digitalization





# Scaling up Sensformer® with advanced and integrated digital offerings for power transformer customers

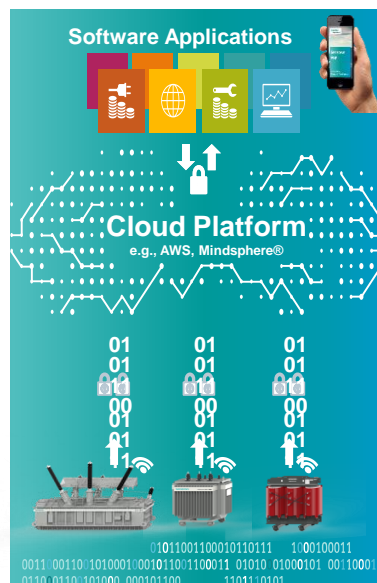
2018



## Entire transformer portfolio

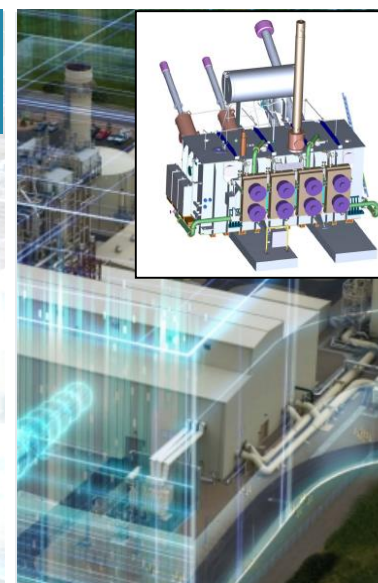
### Added Transparency

- Sensformer APPs incl. Enrichment
- Sensformer Platform
- Sensformer Connectivity device



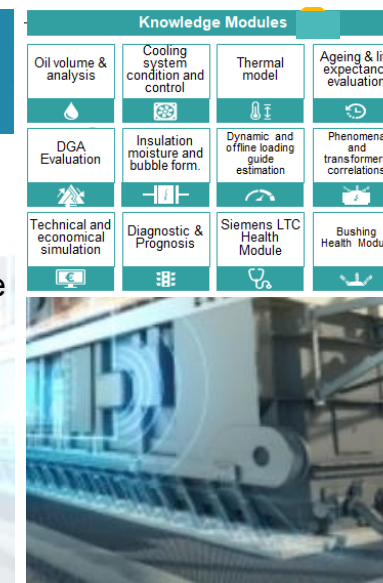
### Enhanced Productivity

- Overload Manager
- Life Consumption
- Temperature Full View



### Advanced Intelligence

- DGA (Hydrogen Gas)
- Bushing Monitoring
- Partial Discharge
- ...further customer use cases



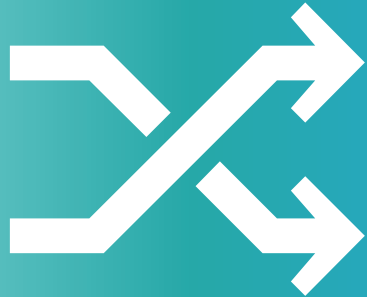
**Sensformer®**

**Sensformer®**  
**Advanced** (Digital Twin)



# Sensformer® advanced offers much higher performance through new features and advanced Apps

## Maximum flexibility



In addition to the basic functionality of Sensformer, the **performance range can be expanded rapidly through Sensformer advanced technology functions**. Tailor-made solutions can be implemented with numerous scaling options

Active Overload prediction

Lifetime prediction

Advanced Sensors

Virtual Sensors

Loadable  
Digital twin Applications

Starter Apps for relevant signals in the transformer

Connectivity and cloud platform

Sensformer  
starter functionality



Electrical  
signals



Weather  
forecast



Load manager



Active Overload  
prediction



Mixed Reality View



Geolocation



Fleet View



Stress map



Virtual Sensors



Aging prediction

More apps to come

# Sensformer® advanced: First reference

## Basslink HVDC Interconnector (Australia)



### Enhanced productivity of customer operating system with digital twin operation

- 400 kV transmission line  
(interconnector between Australia & Tasmania)
- Feature enhancement of an HVDC power transformer
  - Simulation of thermal hydraulic model based on historical operational data
  - Evaluation of lifetime losses for a defined period
  - Simulation of asset life consumption
  - Load prediction for defined period offers a maximum transmission capacity

*“Siemens` continuing close cooperation with Basslink is assisting the development of new predictive software models that will benefit in the ongoing successful operation of the interconnector. Both companies are working collaboratively to reach a favorable outcome.”*

Mark Bostedt, Basslink site engineer



# Sensgear® will increase transparency, productivity and performance of transmission products and systems

2019

## Added Transparency

### Status & Alarms:

- GPS location
- Local weather
- Gas density
- Breaker counter, position, readiness
- Oil level, Top Oil Temperature, LV Winding Current

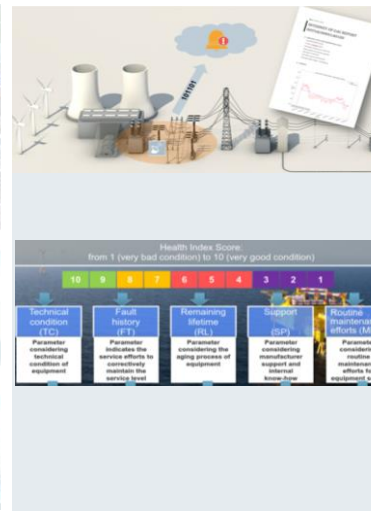


Coming Soon

## Enhanced Productivity

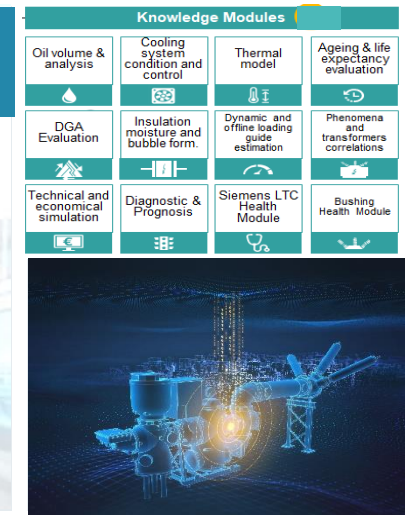
### Reports & Predictions:

- F-gas reports
- Gas alarm predictions
- Health Index reports
- Health Index / Product lifetime prediction
- Overload Management



## Advanced Intelligence

- System and fleet intelligence
- ... further use cases



**Sensgear®**

**Sensgear®  
Advanced**



Electrical signals



Fleet View



Gas density and leakage



Gas Alarms predictions



F-gas reports



Geolocation



Weather



CB counter



Health Index / Lifetime prediction



Active Overload management

More apps to come



# Operational values

## Sensformer® & Sensgear® - Digitalized Transmission Products



### Performance increase



- Load status and prediction of network and products
- Temporary overload management
- Additional power transmission and revenue
- Reduction of unplanned outages
- Asset lifecycle optimization

### Health Safety Environment



- Increased safety through reduced manhours on equipment
- SF<sub>6</sub> leakage and CO<sub>2</sub>e emission reduction
- Oil leakage reduction

### Cost reduction



- Reduction of unplanned outages
- Reduced costs for maintenance from time-based to predictive
- Reduced manhours on equipment
- No costs for SF<sub>6</sub> controlling at site (4/a)
- Reduced costs for SF<sub>6</sub> reporting

### Risk avoidance





- Less risks and costs for unplanned outages
- Less risks and costs for SF<sub>6</sub> leakages and CO<sub>2</sub>e emission penalties
- Less risks and costs for oil leakages

# Sensformer® & Switchgear® – Born Connected

## Transforming data into business value



All **Sensformer®** and **Sensgear™** are equipped to provide following direct measurements per default:


-  GPS Location
-  Local weather information

Additionally all products are equipped with product-specific data:

### **Sensformer and Sensgear ASC:**

-  Oil Level Alarm
-  Top Oil Temperature
-  LV Winding Current


### **Sensgear GIS and Sensgear Circuit Breaker:**

-  Gas Density
-  CB Counter, Position, Readiness
-  Temp.(LCC)

### **Sensgear Arrester**

-  Surge Counter
-  Leakage Current

### **Sensgear Instrument Transformers**

-  Gas Density (GIF)
-  Oil Level Alarm (OIP)

# Sensformer® & Sensgear® App...

## Stay on-grid even when you're off-site



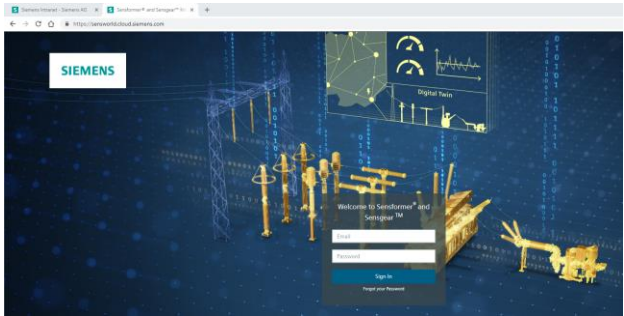
- Secure mobile connectivity
- Instant overview of asset status with real-time data
- Enhanced asset life cycle management
- Key KPIs at a glance
- Optional push messages in case of alarms

# Sensformer® & Sensgear® App Base Functionality

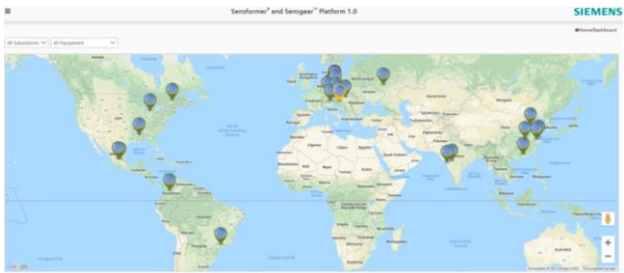
Live Demonstration of Sensformer and Sensgear at Siemens factories



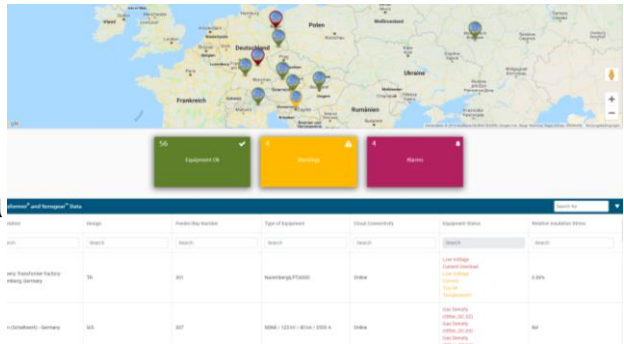
1 Sign in mobile



2 Map with all born connected products and substations

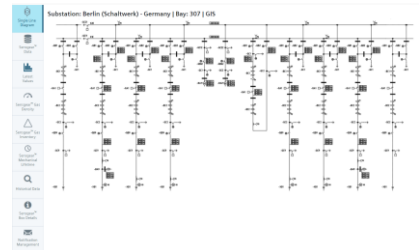


3 OK, Alarms & Warnings list: Location, Equipment, Data



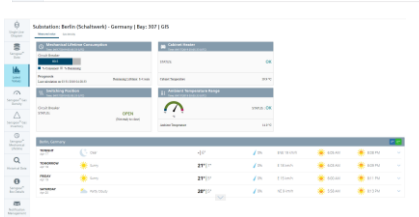
4

Single Line Diagram



5

Sensgear™ Data



6

Latest Values



7

Sensgear™ Gas Density



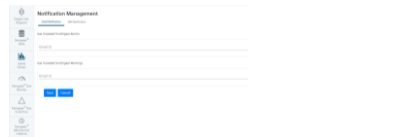
8

Sensgear™ Gas Inventory



9

Sensgear™ Mechanical Lifetime



10

Historical Data



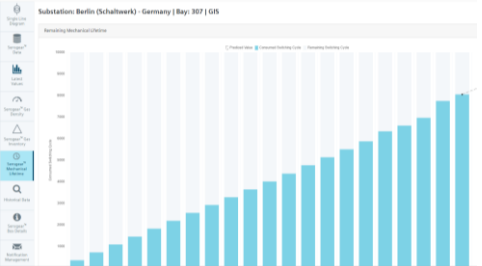
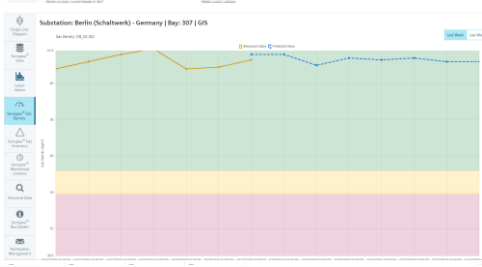
11

Sensgear™ Box Details



12

Notification Management





# Business case of Stromnetz Berlin, German DSO

## Additional autarkic SF<sub>6</sub> GIS - Online Monitoring

### Stromnetz Berlin: Operational experience of autoarkic SF<sub>6</sub> Online Monitoring

#### Aufbau und Betriebserfahrung mit SF<sub>6</sub> Online Monitoring-Systemen

Sascha Czakaj

GIS-Anwenderforum TU Darmstadt  
09. Oktober 2018

Diese Präsentation kann vertrauliche Informationen des Verfassers (s. 1. Sl.) und/oder des Herstellers (s. 2. Sl.) enthalten. Die Weitergabe an Dritte ist untersagt. Bitte beachten Sie die geltenden Datenschutzbestimmungen.

Ein Unternehmen von VAI/TECHNICAL



### Solution: Additional autarkic early warning system installed

#### Digitalisierung der SF<sub>6</sub>-Überwachung

- Idee: Aufbau eines zusätzlichen und autarken Überwachungssystems als „Frühwarnsystem“
- Anforderungen:
  - keine Meldung über die
  - ergänzendes System –
  - keine Ablesungen mehr
  - aufgenommene Daten
  - elektronische Anzeige
  - Nutzung vorhandener

Impressionen der ersten Umspannwerke



### 87 Substation, 62 t SF<sub>6</sub> installed

#### Unsere SF<sub>6</sub>-Erfahrungen

- 1968 - das erste GIS-Schaltfeld von Siemens wurde in Berlin in Betrieb genommen und verrichtet nach wie vor zuverlässig seinen Dienst
- Aktuell 87 Umspannwerke davon 90% in SF<sub>6</sub>
- Ca. 62 t installierte Gesamtmenge SF<sub>6</sub>
- Durchführung von Inspektion, Wartung, Instandsetzung, Diagnose mit eigenem Personal an Schaltanlagen verschiedener Hersteller



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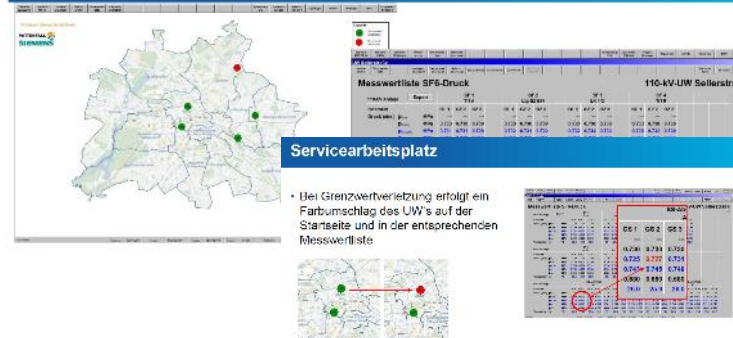
Aufbau und Betriebserfahrung mit SF<sub>6</sub> Online Monitoring-Systemen | Sascha Czakaj | GIS-Anwenderforum TU Darmstadt 09.10.2018

Ein Unternehmen von VAI/TECHNICAL



### Monitoring overview per substation: SF<sub>6</sub> leakage monitored directly: green -> red

#### Servicearbeitsplatz



### All SF<sub>6</sub>-displays manually documented every 3 months at substation

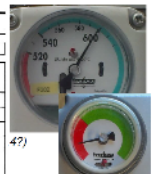
#### Werkskontrollen und SF<sub>6</sub>-Ablesungen

- Ablesung aller SF<sub>6</sub>-Anzeigen durch Betriebspersonal
- Zeitraum der Ablesungen: 3 Monate
- Protokollierung der aufgenommenen Daten im UW
- => Trenden
- => bei Erk

#### Werkskontrollen und SF<sub>6</sub>-Ablesungen

Beispiel Ableseprotokoll:

|                             |  |  |  |  |  |  |  |  |  |                             |  |  |  |  |  |  |  |  |  |
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### All new substation built with autarkic system; No local readouts necessary

#### Aussicht

- Ziel ist es Leckagen so früh wie möglich zu erkennen, um eine mögliche SF<sub>6</sub>-Emission so schnell wie möglich bearbeiten bzw. abstellen zu können
- aktuell werden alle neu gebauten Schaltanlagen mit dieser digitalen SF<sub>6</sub>-Überwachung ausgestattet
- die Realisierung bei den SLT-Projekten wird individuell geprüft und entsprechend umgesetzt
- Die Möglichkeit der Datenspeicherung aller Messwerte ist in Arbeit
- In ertüchtigten Umspannwerken sind zukünftig keine Werksablesungen von SF<sub>6</sub> durch Betriebspersonal mehr notwendig

# Sensgear business case for DSOs and TSOs: HSE improvement, cost reduction and risk avoidance

## Business case of a European system operator of SF<sub>6</sub> GIS

## Sensgear business value for system owners and operators

### Aufbau und Betriebserfahrung mit SF<sub>6</sub> Online Monitoring-Systemen

Sascha Czakaj

GIS-Anwenderforum TU Darmstadt  
09. Oktober 2018

#### Werkskontrollen und SF<sub>6</sub>-Ablesungen

Beispiel Ableseprotokoll:

|                              |     |   |    |          |      |               |     |               |      |
|------------------------------|-----|---|----|----------|------|---------------|-----|---------------|------|
| Anwesenheit                  |     | Nationaler Service Center<br>Hochschulplanung |    | Seite 32 |      | Datum: 4/1/22 |     |               |      |
| Inspektion 1 (Druckablesung) |     |   |    | Werk     |      | Prüfung 802   |     | St. Stadt Nr. |      |
| Druck in bar                 |     |   |    |          |      |               |     |               |      |
| Druck                        |     | Temperatur                                    |    | Druck    |      | Temperatur    |     | Druck         |      |
| G1                           | G2  | G3  | G4 | G1       | G2   | G3            | G4  | Bemerkung     |      |
| 18,5                         | 3,8 | 190   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
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| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
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| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
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| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
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| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
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| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 | 86,51    | 14,8 | 2,3           | 2,3 | 1,48          | 1,48 |
| 1,64                         | 3,2 | 140   | 10 |          |      |               |     |               |      |

Stromnetz  
Berlin



#### Servicearbeitsplatz



#### Servicearbeitsplatz

- Bei Grenzwertverletzung erfolgt ein Farbumschlag des UW's auf der Startseite und in der entsprechenden Messwertliste

#### Werkskontrollen und SF<sub>6</sub>-Ablesungen

- Ablesung aller SF<sub>6</sub>-Anzeigen durch Betriebspersonal
- Zeitraum der Ablesungen: 3 Monate
- Protokollierung der aufgenommenen Daten im UW
- => *Trenderkennung über einen großen Zeitraum möglich*
- => *bei Erkennung erfolgt Information an Fachbereich Schaltanlagen*

#### Aussicht

- Ziel ist es Leckagen so früh wie möglich zu erkennen, um eine mögliche SF<sub>6</sub>-Emission so schnell wie möglich bearbeiten bzw. abstellen zu können
- aktuell werden alle neu gebauten Schaltanlagen mit dieser digitalen SF<sub>6</sub>-Überwachung ausgestattet
- die Realisierung bei den SLT-Projekten wird individuell geprüft und entsprechend umgesetzt
- Die Möglichkeit der Datenspeicherung aller Messwerte ist in Arbeit
- In ertüchtigten Umspannwerken sind zukünftig keine Werksablesungen von SF<sub>6</sub> durch Betriebspersonal mehr notwendig



#### Performance increase

- Load status and prediction of network and products
- Temporary overload management
- Additional power transmission and revenue
- Reduction of unplanned outages
- Asset lifecycle optimization

#### Health Safety Environment

- Increased safety through reduced manhours on equipment ✓
- SF<sub>6</sub> leakage and CO<sub>2</sub>e emission reduction ✓
- Oil leakage reduction ✓

#### Cost reduction

- Reduction of unplanned outages ✓
- Reduced costs for maintenance from time-based to predictive ✓
- Reduced manhours on equipment ✓
- No costs for SF<sub>6</sub> controlling at site (4/a) ✓
- Reduced costs for SF<sub>6</sub> reporting ✓

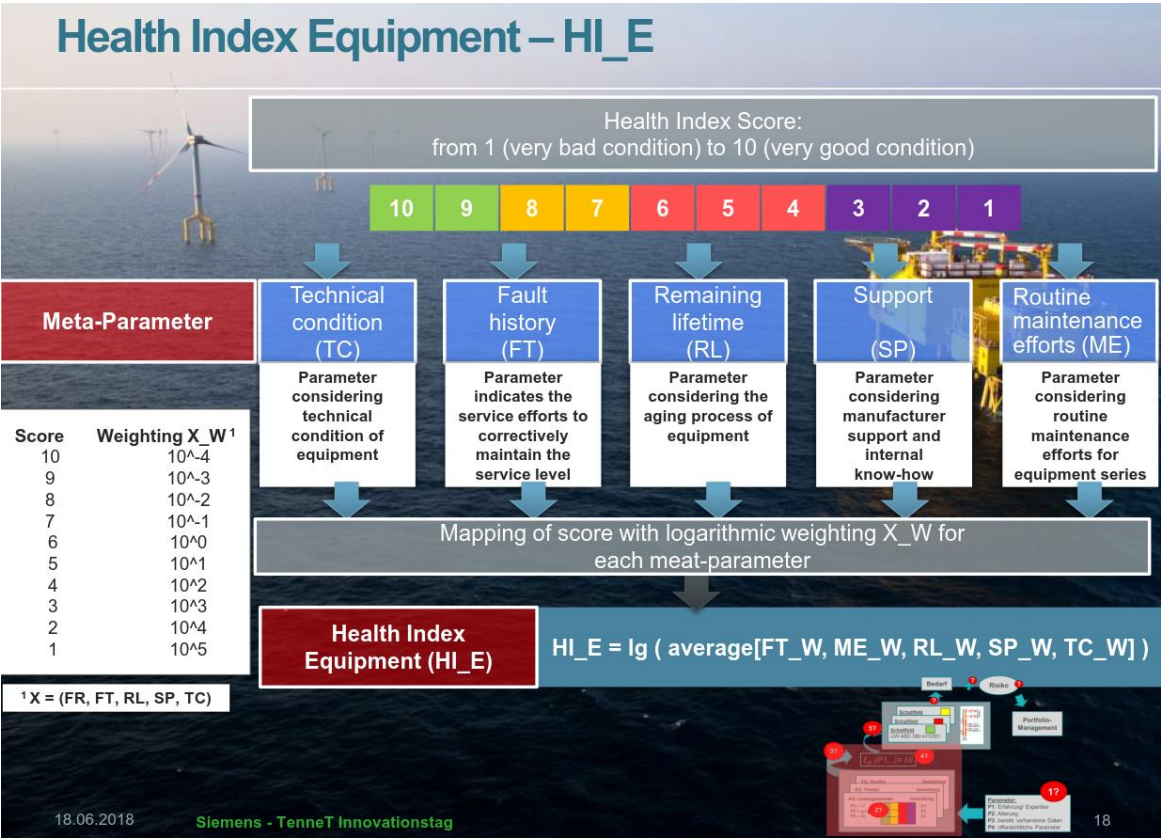
#### Risk avoidance

- Less risks and costs for unplanned outages ✓
- Less risks and costs for SF<sub>6</sub> leakages and CO<sub>2</sub>e emission penalties ✓
- Less risks and costs for oil leakages ✓



# TSO business case: Asset Management based on Health Index per equipment with equipment specific performance models

## Business case: Health Index Equipment Model for Asset Lifecycle Management



## Equipment specific performance models, example TSO

### HIGH VOLTAGE ASSET PERFORMANCE MODELING

EVERT J. DE HAAN, BSC

Master of Science thesis

June 2011

UNIVERSITY Delft University of Technology  
FACULTY Electrical Engineering, Mathematics and Computer Science  
DEPARTMENT Electrical Sustainable Energy  
GROUP High-Voltage Technology & Management



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6 Circuit breaker failure rate estimation model

### 6.1 Failure modes

In general there are two types of failures: major and minor failures. When a major failure occurs, the circuit breaker loses one or more of its fundamental functions and either backup equipment needs to take over or immediate unscheduled maintenance is required [2]. A minor failure is every failure that does not classify as a major failure. Since minor failures occur more often than major failures [35], they might be of more interest for modeling the failure rate of the asset. However, keeping in mind that the asset failure rate estimation model is meant to calculate the failure rate, which will be used to calculate a failure risk, the major failures are of more interest. As major failures are most detrimental to the proper functioning of a circuit breaker and will cause a larger failure impact than minor faults, the emphasis is on them.

Within the set of major failures there are several failure modes: major failure modes. During the second international inquiry on high voltage circuit breaker failures and defects in service Cigré held ([35]), they asked respondents to indicate by which failure mode the circuit breaker failed. The frequency distribution for major failure modes is shown in Table 6.1.

Table 6.1: Percentage of failures per circuit breaker major failure mode [35]

| Failure mode                          | Percentage |
|---------------------------------------|------------|
| Does not close on command             | 24.6 %     |
| Does not open on command              | 8.3 %      |
| Closes without command                | 1.1 %      |
| Opens without command                 | 7.0 %      |
| Fails to carry the current            | 1.5 %      |
| Breakdown to earth                    | 3.2 %      |
| Breakdown between poles               | 1.5 %      |
| Does not make the current             | 1.7 %      |
| Breakdown across open pole (internal) | 3.6 %      |
| Does not break the current            | 3.0 %      |
| Breakdown across open pole (external) | 1.5 %      |
| Locking in open or closed position    | 28.4 %     |
| Others                                | 14.6 %     |

Table 6.1 shows that *Does not close on command*, *Does not open on command* and *Locking in open or closed position* are the most common major failure modes for a circuit breaker. Since the latter occurs most often, using that failure mode will result in the largest amount of failure data which is beneficial when deriving the failure rate distributions.

In Section 1.4.2 was stated that an increasing number of asset subpopulations decreases the number of failure data points per subpopulation. Likewise, a large amount of failure modes results in a low amount of data available per failure mode. To increase the number of failure data points per failure mode, the failure modes can be divided into groups which have about the same behavior. The behavior should both with respect to failure rates and with respect to failure impacts be about the same. Else the failure risk that would be calculated based on them would not be an accurate representation of reality.

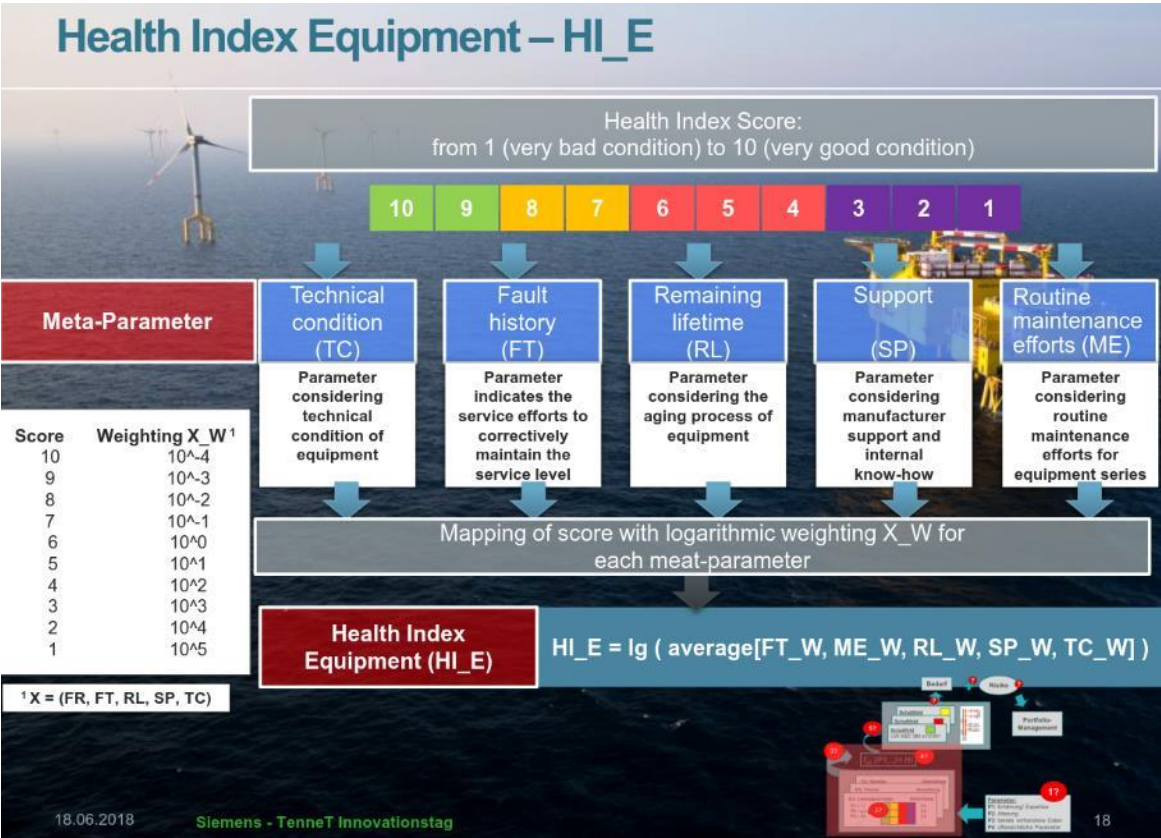
Whether the failure rate behavior of the failure modes is alike is normally assessed in the asset function. If the failure modes describe the same asset failure causes their areas in a

Source: Evert J. de Haan, High Voltage Asset Performance Modelling, Tennet & TU Delft

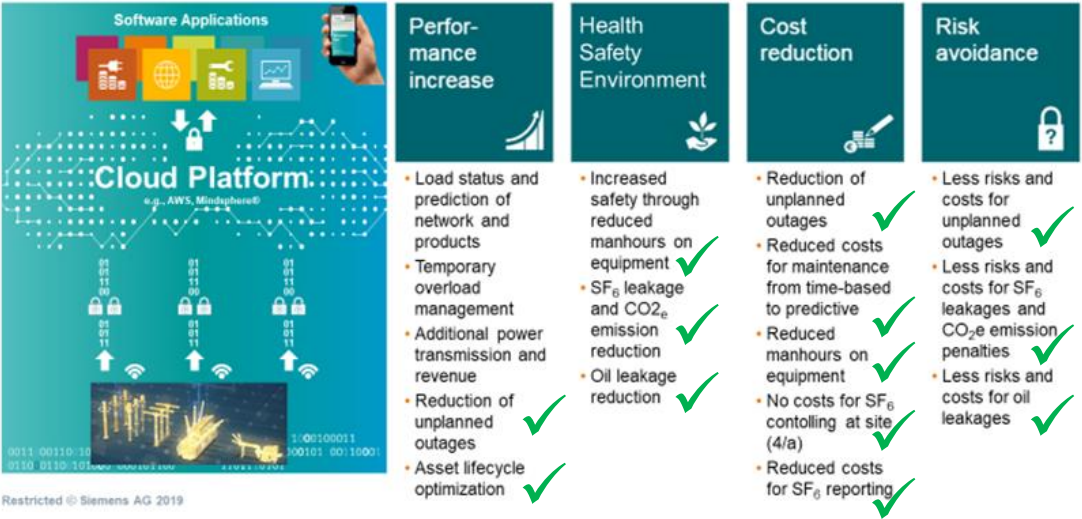


# Sensgear business case for TSOs and DSOs: Health Index per equipment for optimized Asset Management

Business case:  
Health Index Equipment Model for Asset Management



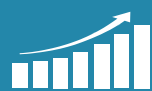
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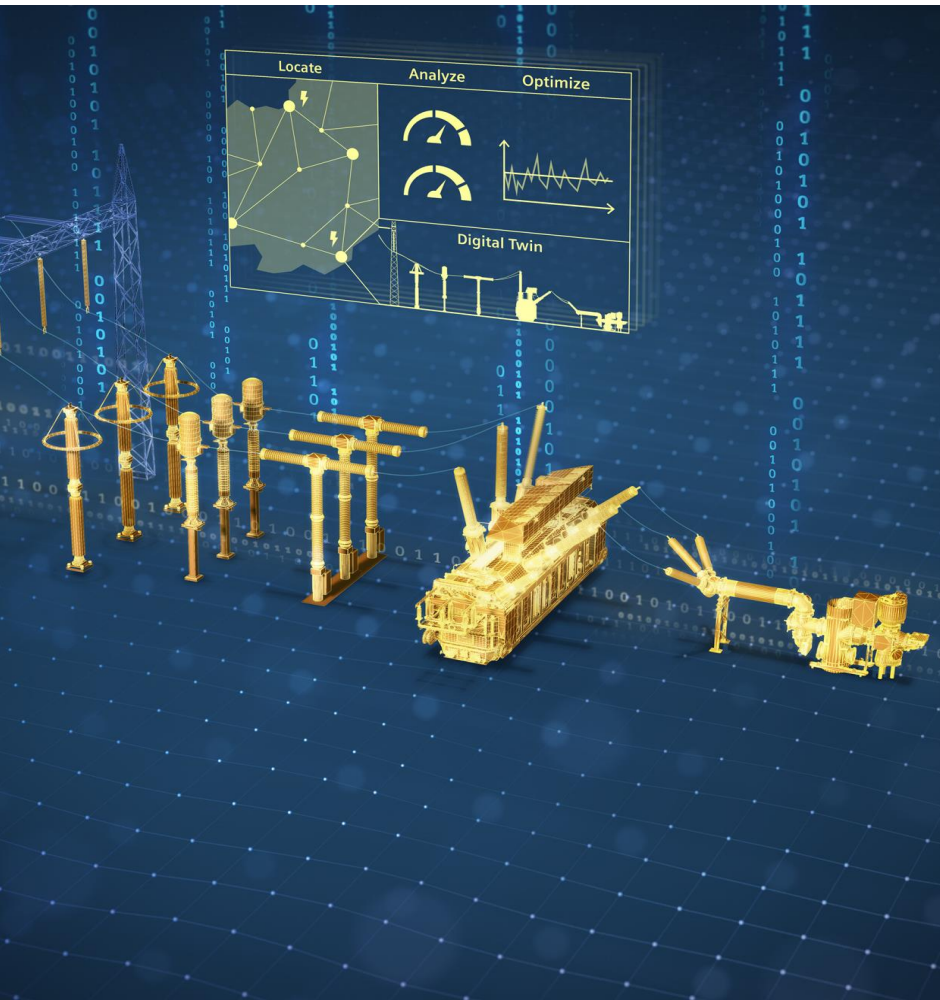
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Thanks for your attention  
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