Digitized high-voltage products
Sensformer® and Sensgear® - Outlook
Dr.-Ing. Dirk Helbig | Senior Principal High Voltage Products & Innovationmanager
Digitalized Transmission Products: Sensformer® & Sensgear®

Table of content

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**
- Growing share of Renewables
- System complexity and reliability
- Performance & Availability
- Health, Safety & Environment
- Decentral Grids & Prosumers
- Rapid Electrification
- Cost reduction
- Growing share of Renewables
- System complexity and reliability
- Performance & Availability
- Health, Safety & Environment
- Decentral Grids & Prosumers
- Rapid Electrification
- Cost reduction
- Socio-demographic changes

**Opportunities**
- Sensors & IOT
- Cloud
- Communications
- Smart data
- Rapid Electrification
- Cost reduction
- Socio-demographic changes
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 SF₆ 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

**Cost efficient**
- 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 SF₆ 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

- Air insulated substation
- Gas insulated substation
- Power quality

System:
- Product
  - Voltage Transformer
  - Current Transformer
  - Bushing
  - GIS
  - Line Traps
  - Coils
  - Reactors
  - Phase Shifter

Product:
- Insulators
- Circuit Breaker
- Disconnector
- Arrester
- Transformer

Sensors and connectivity; control, protection and automation; medium voltage; parameterization, system engineering; HV connection between AIS/GIS and transformers
The journey started 2018
Sensformer® enable our customers to get digitally connected

Therefore we started the journey from Transformers to Sensformer®

Physics will always stay the same.
In the digital age it merges with information – creating benefits to manage changing power systems.
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

“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.

• 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
The journey continues
Extending the approach to entire Transmission Products family

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

**Entire transformer portfolio**

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

**Power transformer portfolio**

- 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

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**
- **Starter Apps for relevant signals in the transformer**
- **Connectivity and cloud platform**

Digital twin Applications:
- **Loadable**
- **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.

**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® Advanced**
- Sensgear® will increase transparency, productivity and performance of transmission products and systems.
- 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®**
- Electrical signals
- Fleet View
- Gas density and leakage
- Gas Alarms predictions
- F-gas reports
- More apps to come

**Geolocation**
- CB counter
- Health Index / Lifetime prediction
- Active Overload management

**Weather**
- 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

**Unrestricted © Siemens 2019.**

Page 16 June 27, 2019

Dr.-Ing. Dirk Helbig / Transmission Products
Operational values
Sensformer® & Sensgear® - Digitalized Transmission Products

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

- Increased safety through reduced manhours on equipment
- SF₆ leakage and CO₂ₑ emission reduction
- Oil leakage reduction

- Reduction of unplanned outages
- Reduced costs for maintenance from time-based to predictive
- Reduced manhours on equipment
- No costs for SF₆ controlling at site (4/a)
- Reduced costs for SF₆ reporting

- Less risks and costs for unplanned outages
- Less risks and costs for SF₆ leakages and CO₂ₑ 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

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 SF₆ GIS - Online Monitoring

Stromnetz Berlin: Operational experience of autarkic SF₆ Online Monitoring

87 Substation, 62 t SF₆ installed

Unsere SF₆-Erfahrungen

- 1998 - das erste GIS-Sicherfeld von Siemens wurde in Berlin in Betrieb genommen und vermittelt noch vor zentralisieren Dienst
- Aktuell 87 Umspannwerke davon 90% in SF₆
- Ca. 62 t installierte Gesamtmenge SF₆
- Durchführung von Instandsetzung, Wartung, Inspektions- und Diagnose mit eigenem Personal an Schaltanlagen verschiedenster Hersteller

Monitoring overview per substation: SF₆ leakage monitored directly: green -> red

Servicearbeitsplatz

All SF₆-displays manually documented every 3 months at substation

Solution: Additional autarkic early warning system installed

Digitalisierung der SF₆-Überwachung

- Idee: Aufbau eines zusätzlichen und autarken Überwachungssystems als „Frühwarnsystem"
- Anforderungen:
  - keine Meldung über das „ergänzende System“
  - keine Ablesegeräte mehr
  - aufgenommene Daten:
    - elektronische Anzeige
    - Nutzung vorhandener (ungestörter) Daten

Monitoring overview per substation: SF₆ leakage monitored directly: green -> red

Servicearbeitsplatz

All new substation build with autarkic system; No local readouts necessary

Aussicht

- Ziel ist es Leckagen so früh wie möglich zu erkennen, um eine mögliche SF₆-Emission so schnell wie möglich behoben bzw. abzustellen zu können
- aktuell werden alle neu gebauten Schaltanlagen mit dieser digitalen SF₆-Überwachung ausgestattet
- die Realisierung bei den SLT-Projekten wird individuell geprüft und entsprechend umgesetzt
- die Möglichkeit der Datenübertragung aller Messwerte ist in Arbeit
- In ersetzen Umspannwerken sind zukünftig keine Werkssä_ES von SF₆ 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\textsubscript{6} GIS

Sensgear business value for system owners and operators

- Load status and prediction of network and products
- Temporary overload management
- Additional power transmission and revenue
- Reduction of unplanned outages
- Asset lifecycle optimization
- Increased safety through reduced monitors on equipment
- SF\textsubscript{6} leakage and CO\textsubscript{2} emission reduction
- Oil leakage reduction
- Reduction of unplanned outages
- Reduced costs for maintenance from time-based to predictive
- Reduced monitors on equipment
- No costs for SF\textsubscript{6} contamination at site
- Reduced costs for SF\textsubscript{6} reporting
- Less risks and costs for SF\textsubscript{6} leakages and CO\textsubscript{2} emissions
- 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

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 both backup equipment needs to take over or immediate unplanned 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 [3], 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 major failure modes. During the second international inquiry on high voltage circuit breaker failures and defects in service Cigre held [135], 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.

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

Unrestricted © Siemens 2019.
Sensgear business case for TSOs and DSOs: Health Index per equipment for optimized Asset Management

Business case:
Health Index Equipment Model for Asset Management

Health Index Equipment – HI_E

Health Index Score:
from 1 (very bad condition) to 10 (very good condition)

10 9 8 7 6 5 4 3 2 1

Meta-Parameter

Score Weighting X_W
10 10^-4
9 10^-3
8 10^-2
7 10^-1
6 10^0
5 10^1
4 10^2
3 10^3
2 10^4
1 10^5

HI_E = lg (average[FT_W, ME_W, RL_W, SP_W, TC_W])

Sensgear business value for system owners and operators

- Load status and prediction of network and products
- Temporary overload management
- Additional power transmission and revenue
- Reduction of unplanned outages
- Asset lifecycle optimization
- Increased safety through reduced manhours on equipment
- SF6 leakage and CO2e emission reduction
- Oil leakage reduction
- No costs for SF6 containing at site (48)
- Reduced costs for SF6 reporting
- Reduced costs for unplanned outages
- Less risks and costs for SF6 leakages and CO2e emission penalties
- Less risks and costs for oil leakages

Restrict © Siemens AG 2019
Sensformer® and Sensgear® generate additional operational values through merging transmission products with digitalization.

**Operational Values**

- **Performance increase**
- **Health Safety Environment**
- **Cost reduction**
- **Risk avoidance**

**Sensformer® & Sensgear®** - Added transparency, enhanced productivity and advanced intelligence

- **Software Apps & Digital services**
  - Data generation, collection, analysis and utilization

- **Standardized, quality focused and digitally optimized products**

Digital transformation of products and factories.

Increase value.
Thanks for your attention
Let us connect and create value together

Dr.-Ing. Dirk Helbig
Senior Principal High Voltage Products

Siemens AG
Transmission Products / Digital Enterprise
Freyeslebenstr. 1
91058 Erlangen

Mobil:  +49 173 255 89 08
E-Mail:  dirk.helbig@siemens.com

siemens.com/sensformer
siemens.com/sensgear
sensgear sensformer webinars
Disclaimer

Subject to changes and errors. The information given in this document only contains general descriptions and/or performance features which may not always specifically reflect those described, or which may undergo modification in the course of further development of the products. The requested performance features are binding only when they are expressly agreed upon in the concluded contract.

All product designations, product names, etc. may contain trademarks or other rights of Siemens AG, its affiliated companies or third parties. Their unauthorized use may infringe the rights of the respective owner.