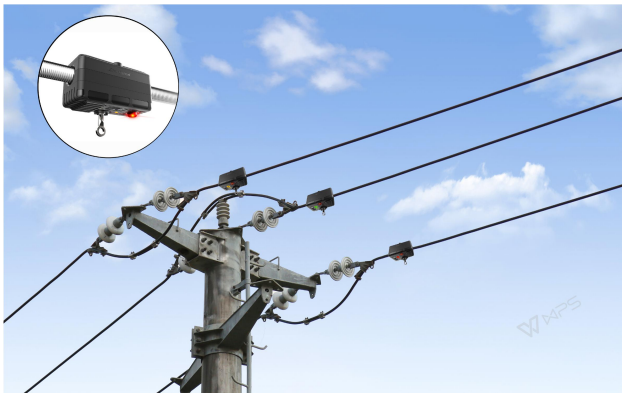
Smart Distribution Network Monitoring System



LinePatrol®

Smart Grid Sensor (SGS)

+

SFPlatform

Cloud-based Big Data Analysis

System Description

Nowadays utilities are facing the requirements to improve the reliability for distribution grid, while operating and maintaining aging infrastructure with limited budgets. Silverfern Power (SFP) equips utilities withSmart Distribution Network Monitoring System to meet these challenges.

SFP's Smart Distribution Network Monitoring System consists of LinePatrol®, a high precision wide-area timing synchronized smart grid sensor (SGS) and SFPlatform, a Cloud-based Big Data Analysis platform.

SGSs can be easily installed on both overhead power lines and underground cables. They are used to measure the line current, temperature and voltage (on demand) with high precision and accurate timing synchronization. Any faults and disturbances in the distribution network can be captured and the waveform data are first stored locally and then transmitted to Cloud-based SFPlatform via Internet of Things.

SFPlatform collects, records and analyzes the timing synchronized data over time and provides utility operators with insights into the feeders and system-wide network.

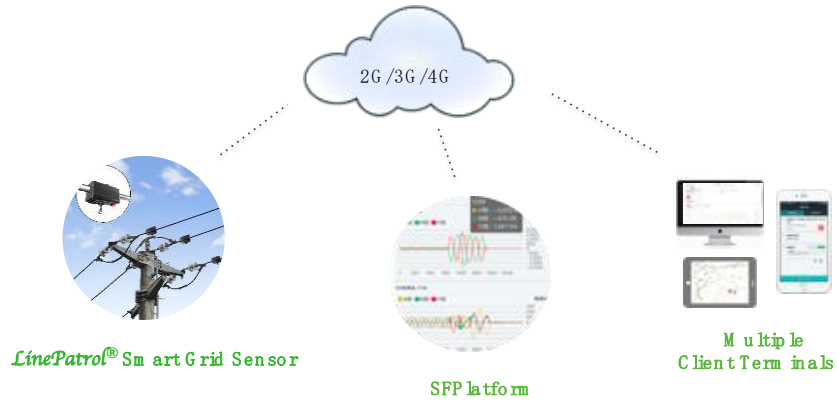
This monitoring system is a wide area timing synchronized system. Measuring data from the SGSs on different locations among the distribution network are time stamped and aligned in micro-second. It provides utilities with high quality, time coherent data throughout their distribution networks, allowing them to improve reliability and efficiency while reduce the operational cost.

Taking advantage of big data analysis, the system identifies not only faults but also abnormal disturbances, and then alerts operators visually and notifies repair crews via SMS and APP in time, which helps to reduce outage duration and enables faster response to lower SAIDI and CAIDI.

LinePatrol® Smart Grid Sensor (SGS) + Cloud-based Big Data Analytical Platform (SFPlatform)

Applications

- Asset performance management
- Faulted line selection and location
- Distributed event waveform recording
- Load monitoring
- Bidirectional power flow support
- Dynamic line rating



- SGS can be used to measure power line current, temperature and voltage. All the sampling data from each device have a time stamp with unit of micro-second, which means all these data sampling is fully synchronized within 1 us. It is particularly applicable for building a Wide Area Measurement System (WAMS) for power distribution network.
- Each SGS integrates wireless data modules to communicate with SFPlatform or Main Station via 2G/3G/4G.
- SGS is inductively self-powered with no pole-mounted power supply equipment required.
- SFPlatform is modular, highly flexible and scalable. Management module provides SGS's management for efficient rollout deployment and maintenance. While analysis modules turn the collected raw data into the critical information as well as the visibility of distribution network.

Applications

1) Load Monitoring

SFP's Smart Distribution Network Monitoring System continuously measures current, temperature and voltage and calculates harmonics and three phase imbalance which are necessary for load monitoring.

The data can be transmitted to Cloud Platform by using two different modes:

- Report at a user-defined time interval from 1 second to 2 hours

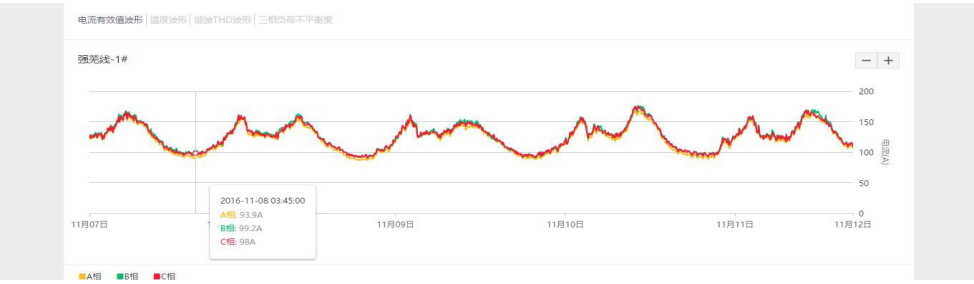
  The time interval is set to 5 minutes by default. It can be remotely modified over-the-air at any time.

- Report the event triggered by an exception

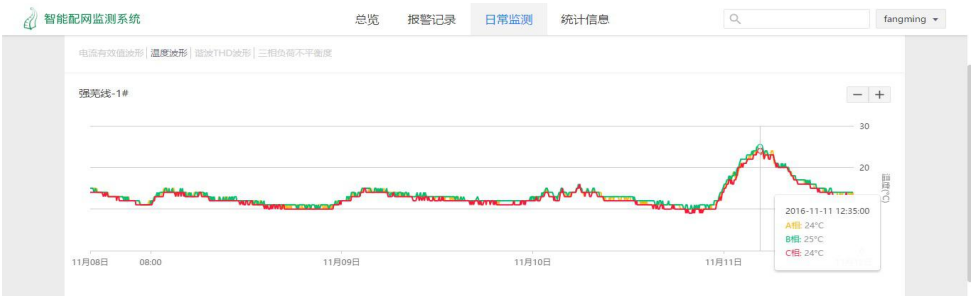
  When current or temperature exceeds the user-defined alarm threshold, an alert will be sent to SFPlatform to inform that an exception has occurred. Alarm thresholds can be remotely set over-the-air at any time.

All the data are stored in the database permanently and can be used for big data analysis of power system.

The web application and smartphone APP gives the visibility of load conditions. The utilities can maximize asset utilization by making sound decisions on asset replacement and network operation based on accurate real data rather than traditional best-guess simulations or state estimations.



Real-time Load Current



Real-time Line Temperature

Real-time Harmonics THD

Three-Phase Imbalance Ratio

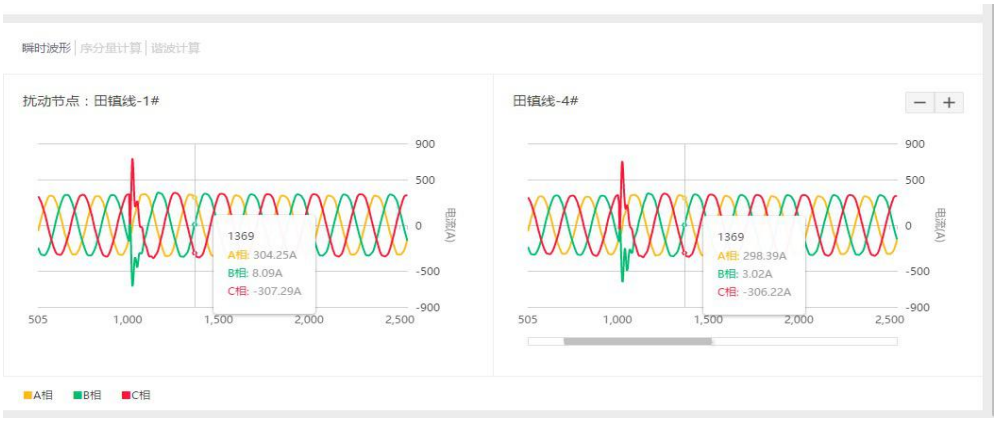
Monthly Load Statistics

2) Distributed Event Recorder

SFP's Smart Distribution Network Monitoring System enables utilities to analyze network events by capturing and analyzing the unique waveform signature generated by the event. Detailed oscillography can be captured at all deployed locations across the distribution grid allowing for precise event location, measurement and cause diagnosis. Complete waveform data is not only stored locally on device, but also uploaded to SFPlatform, allowing for detailed evaluation of power system disturbances.

Waveform data is captured at 256 samples per cycle, exceeding the sampling rate of most substation-based equipment.

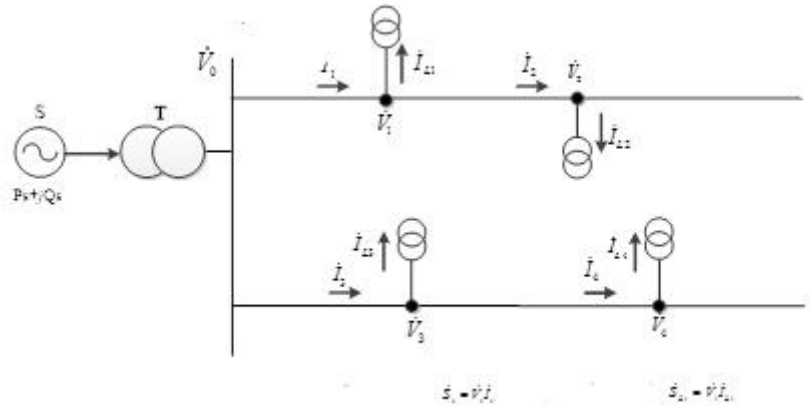
Therefore, the traditional assembly waveform recorder used in substation can be replaced by this distributed event recorder system. It is especially suitable for disturbance analysis and post fault analysis.



Waveform Signature Generated by Event

3) Wide Area Timing Synchronized Instantaneous Measurement

Based on the wide area timing synchronized instantaneous measurement data, the real-time power flow and line loss of distribution network can be derived. It is helpful for optimizing the grid operation and can generate some sound economic benefits.



4) Power Theft Detection and Status Monitor for Equipment used in Distribution Network

According to the measured current and voltage data, the power consumption of end users can be monitored on the high voltage side in order to detect the power theft. So does the operation status of Equipment such as transformers etc.

High Voltage Side Abnormal Current of the Load Transformer

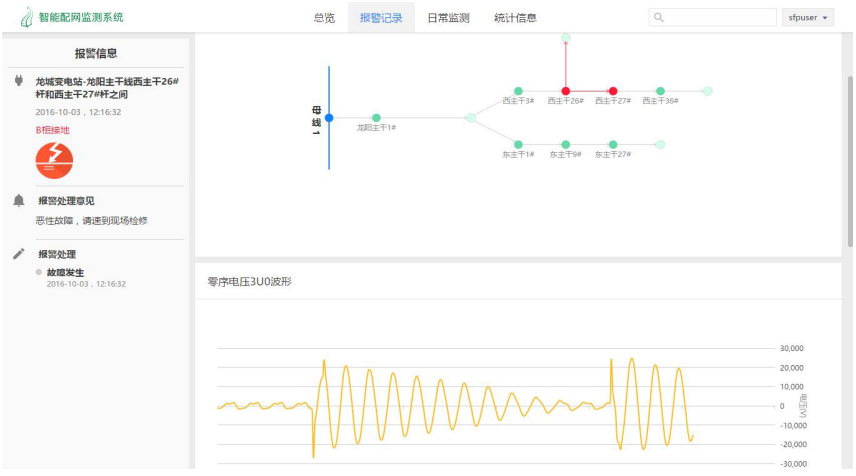
5) Fault Location and Pre-fault Identification

Traditional fault indicators (FCIs) were useful sometimes, but their functionality, reliability and lifespan were limited. Most of them have a non-chargeable battery inside, and once the battery run out of power, these FCIs won't work anymore.

SGS has no need for battery. It generates all the power needed from magnetic field surrounding the conductor. This power harvesting technology plus the elaborate power management strategy enables SGS to fully operate when the line current is not less than 6A.

By analyzing high fidelity waveform data, SFP's monitoring system can

- detect fault location, alert operators visually and notify repair crews via SMS and APP automatically. Furthermore, an operator can dispatch the crew to the correct location based on an immediate alert notification. Together with sectionalizing switches and fuses, fast fault isolation can be quickly realized.
- sense pre-fault anomaly, shift utilities from reacting to outages to preemptively tackling issues that may cause outages in the future, including insulator leakage, excessive arcing during capacitor switch operations and loose connectors etc.
- In ungrounded neutral grounding system (UNGS), about 80% faults are Single-Phase Earth Faults. Since it only leads to a slightly disturbance during very short period (in several millisecond) at the very beginning of the fault, this kind of faults are difficult to be detected and identified and quite often are missed or false reported. Nevertheless, powered by hi-definition waveform data and multiple dedicated algorithms, SFP's monitoring system can quickly sense and properly identify them. As long as the zero-sequence current caused by fault is above 1A, the system can accurately detect and locate single-phase earth faults at nearly 100% rate.



Single-Phase Earth Fault Detection & Notification

Key Features

1) Data Synchronization

Data from all deployment locations across the distribution network are timing synchronized and aligned within 1us.

2) Inductively Power Supply & Noninvasive Installation

The device is self-powered and supports noninvasive installation using a hot-stick or hot-glove in a minute. There is no need of extra cable wiring or routing.

3) High Precision & High Sampling Rate

Data are sampled at 256 samples per cycle with 16 bits. It is critical for Single-Phase Earth Fault analysis, detection and location.

4) Single-Phase Earth Fault Detection & Location

The fully timing synchronized wide area data are captured and analyzed using the advanced intelligent algorithms, the fault can be detected and located accurately and quickly.

5) Equipotential Design

The device is equipotential to the power line. There is no insulation risk.

6) Remotely Configurable & Upgradeable

The device is software-defined and over-the-air upgradeable to eliminate maintenance costs.

Specifications

Design Electrical Frequency	50Hz/60Hz
Line Voltage Rating	6～110kV
Off Peak Line Current	6A at full operation
Operating Temperature	-40˚C～ 85˚C
Conductor Diameter	8mm～40mm
Timing Synchronization	1us
Voltage Measurement Precision	1%
Current Range & Precision	0～100A: ±0.5A, 100~600A: ±0.5%, >600A: ±10%
Sampling Rate	256 samples/cycle
Power Quality	Computes amplitude of voltage/current up to the 13th harmonic
Fault Current Range	0～10kA RMS fault current
Waveform Record Length	400ms default (configurable)
Number of Records	1000
Temperature Range & Precision	-40˚C~125˚C/±1˚C
Local Communication	2.4GHz
Long Distance Communication	2G/3G/4G
Communication Protocol	IEC 60870-5-101/104
Dimensions (H*W*L)	220 mm×130 mm×110mm
Weight	2.95kg
Installation	Hot-stick with no pole-mounted equipment
Ingress Protection	IP66
Flame Retardant Rating	V0
Life Cycle	>8 years

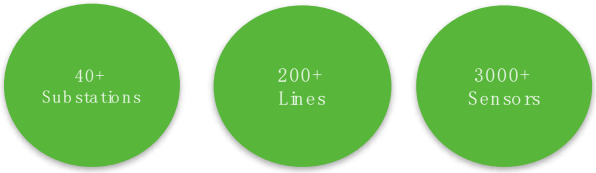
Cases

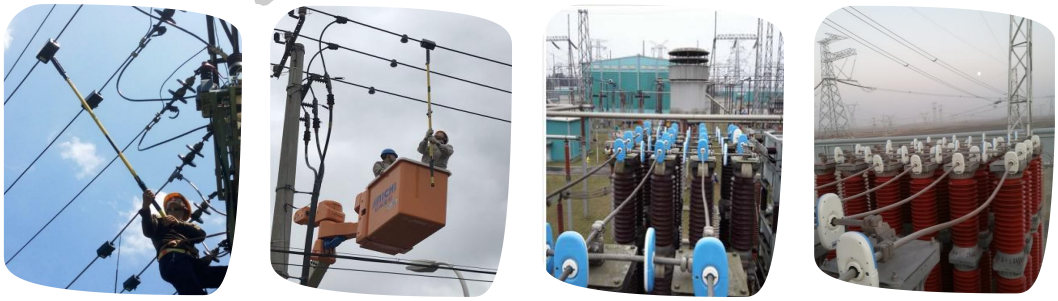
1) Distribution Network

Since April 2015, dozens of Smart Distribution Network Monitoring Systems with thousands of sensors have been put into field operation.

The unknown operational status of distribution network for utilities in the past has become completely visible since the systems are in service. The system monitors the distribution network 24/7 for events and faults. With the help of the system, inspection crews improve their efficiency greatly and the outage time is significantly shortened.

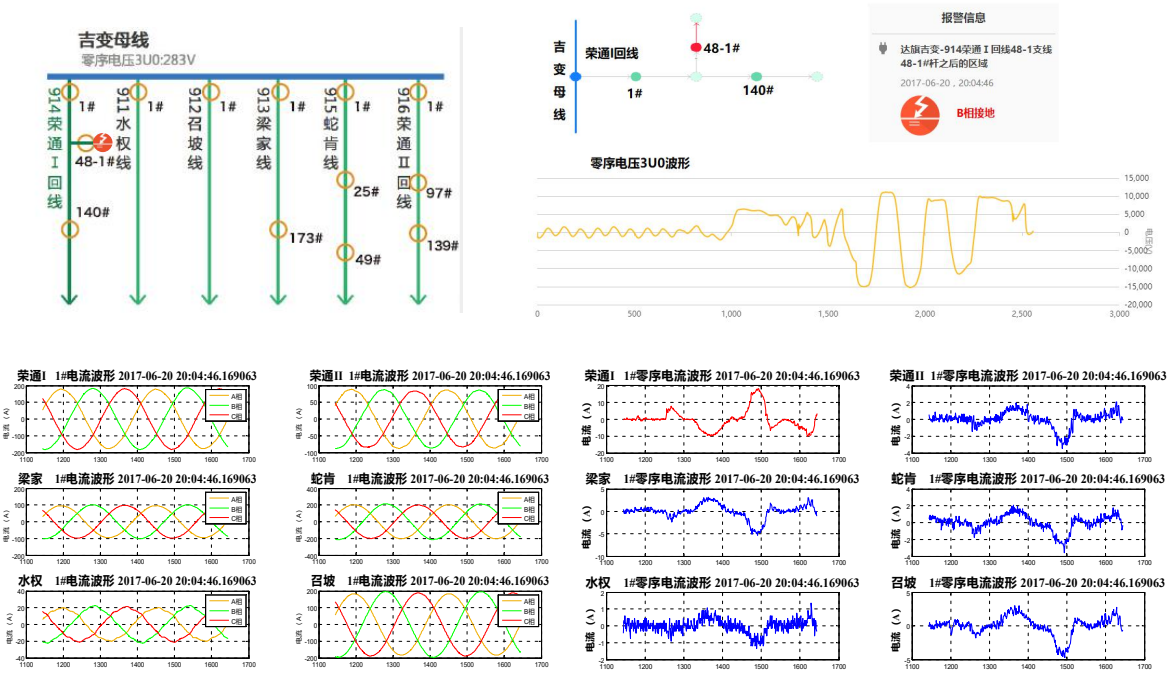
Field operation > 42 months
(By E2018)





10kV QS Line (Suzou, JS)	10kV LY Line (Luohe, HN)	35kV SJ Line (Erdos)	10kV HX Sta. (Yingtan, JX)	10kV DJ Sta. (Jinan, SD)	10kV MH Sta. (Shanghai)

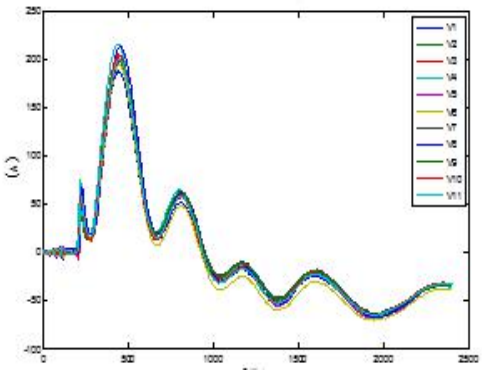
An Earth Fault Case



The figure above shows a 35kV substation with six 10kV lines. By analyzing the waveforms of three phases current, the zero-sequence voltage and the zero-sequence current, the system automatically outputs the result: B phase earth fault after pole 48-1# of RT I Line @2017-06-20 20:04:46.169063.

2) **HVDC (High Voltage Direct Current) Convertor Station**

Based on the same principle, a new Online Monitoring System of the Surge Arrester for HVDC Projects has been developed. The system is used to assess the key equipment performance by monitoring the current flow of the parallel arresters applied for overvoltage protection in HVDC convertor stations. Once the current deviation between parallel arresters exceed 5%, some of the arresters must be replaced early in order to avoid the unscheduled shutdown of the HVDC transmission caused by the damaged equipment. The monitoring system has been used in 9 HVDC Projects of State Grid, such as Fulong, Yibin, Jinping, East Yinchuan, Tianshan, and Zhalute etc. It guarantees the safety and reliability of the HVDC Transmission System.



Configurations

LinePatrol® SGSs can be installed via hot-stick in a minute. Neither extra space nor any infrastructure is needed.

It is especially suitable for the distribution network which has a very complex topology and large number of sub-feeders and laterals. It helps to easily get measurement data anywhere and anytime without additional supporting infrastructure requirement.

The more SGSs are installed, the more transparency and visibility of the distribution network are available to utilities.

It is recommended that SGSs be installed every 2~3 kilometers for main or important lines. The faults can be located precisely so that the outage time can be significantly reduced.

There are three possible configurations:

- Basic Monitoring System

  One SGS is installed in the substation to measure the zero-sequence voltage of a bus，and two groups of SGSs are installed on both ends of every feeder to measure the three-phase current. In this way, the faulted lines can be easily selected.

- Advanced Monitoring System

  Based on the above scheme, two more groups of SGSs can be installed on both ends of each feeder to measure the line voltage. With the simultaneously sampled current and voltage, the power flow and line loss can be calculated. It makes the distribution network entirely transparent and visible.

- Combined with Smart Switch for Fast Fault Isolation

  More groups of SGSs can be installed at the position of smart switches so that the faulted section can be precisely determined and quickly isolated via the switches.