Optoelectronic Arc Detection
and
Optical Partial Discharge System

1. Contents

2. Company

In 1986 Dipl.-Ing. Franz Vogl set up the Vogl Electronic GmbH. Our own development, in close accordance with the latest technical standards of SF6-insulated high voltage switchgears and air-insulated medium voltage switchgears, guarantees the reliability of the system.

Not only across Europe but also in countries outside, the system had been largely contributing to the reliable electrical power supply for more than 30 years.

Since 2007, Vogl Electronic GmbH has intensively engaged in the development of partial discharge systems among other innovations.

Figure 1: Research&Development (top left), High voltage test field (top right), Head office (bottom)

3. Optical Arc Detection System (LiBo)

3.1. System description

The optoelectronic arc fault detection enables a gas-compartment-accurate location of the electric arcs in a metal-enclosed switchgear. During this process, occurring arcs are located via the connected fiber optic cable and are reported on site and to the station control system.

The maintenance or control center receives accurate information about the flaw location. As a result, rapid switching measures can be initiated without the risk of a faulty circuit.

Thus, in the event of a fault, the exact determination of the location is evaluated by the system. This makes a complex manual fault location determination no longer necessary and increases the availability of the GIS or GIL.

The diagnostic system can be used both in staffed or remote-controlled unoccupied switchgears of medium, high and maximum voltage.

Figure 2: GIS with arc detection system

The scope of application extends from fault arcs in the kA range in solidly grounded systems, to currents in the ampere range at compensated systems, through detection of arcing in the on-site high voltage test. A safe detection of flash-overs, both in the AC voltage test as well as in switching and lightning impulse voltage test is guaranteed.

In addition to being used in new systems, the system can also be retrofitted for existing systems and is suitable for the use in SF_6-insulated high voltage systems from 60 kV to 1000 kV.

The system is also available for air- and gas-insulated medium voltage switchgears.

Figure 3: GIS with arc detection system

3.2. Theory of operation and components

The LIBO system from Vogl Electronic GmbH consists of three main components:

1) **Light sensor** - which "picks up" arcs in a GIS
2) **Fiber optic cable** - as a transmission path to the evaluation electronic
3) **The evaluation electronic** - which informs the maintenance or control center about faults

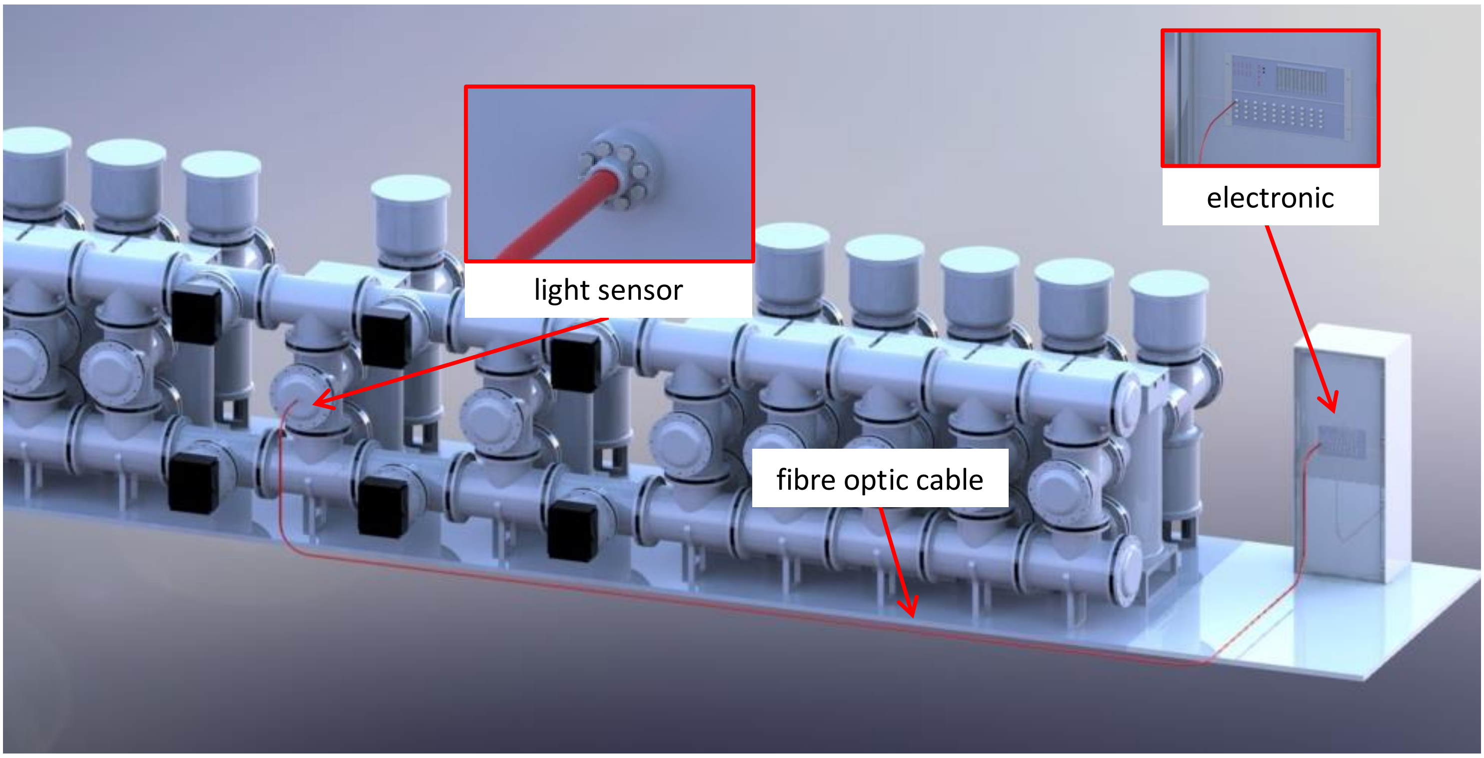
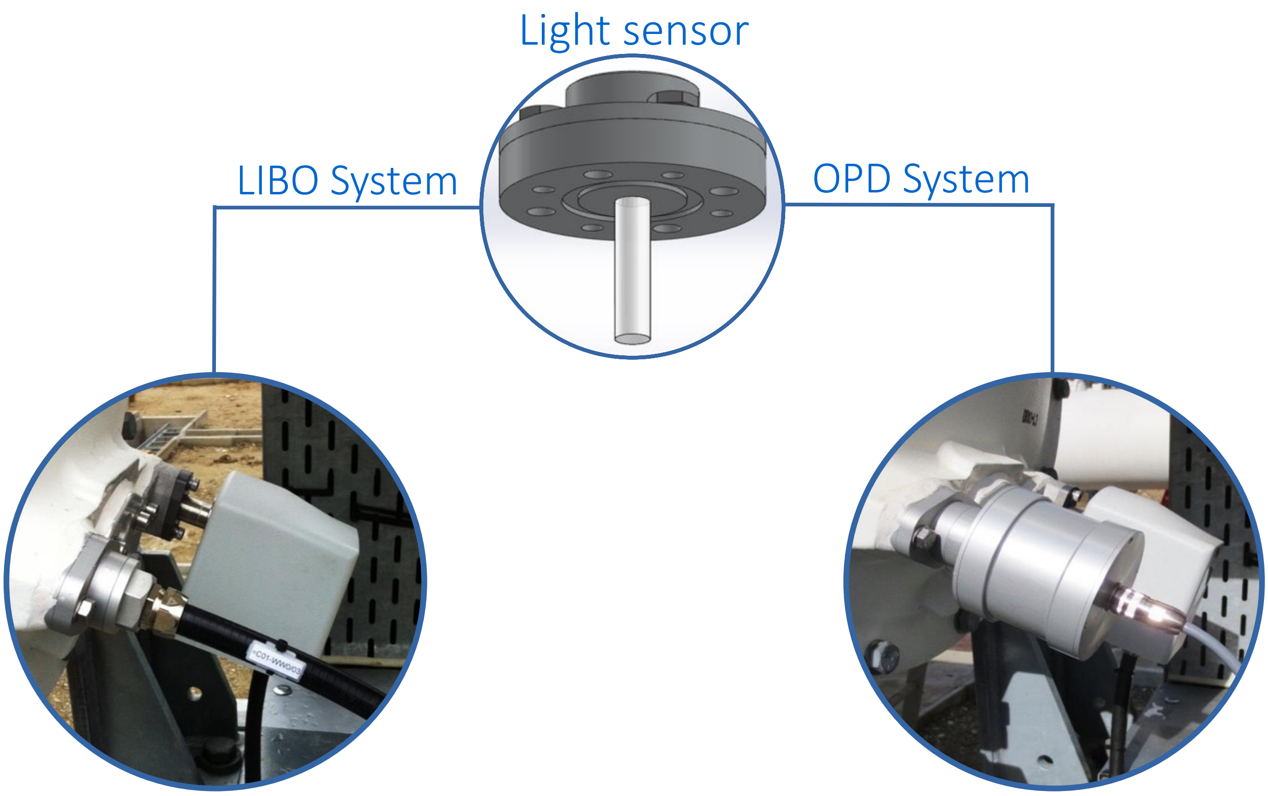


Figure 4: LIBO system

3.2.1. Light sensor

The light sensor is a passive element that allows an insight into the gas-insulated switchgear, like an inspection glass. This can be installed on all existing openings of a GIS. The light sensor enables the installation of the following two optical systems:



Arc detection system
Light sensor and fiber optic cable
in a protective hose

OPD equipment to check for
optical partial discharge

The costs for the sensors during a system installation are insignificant and they can easily be mounted on existing openings of a GIS. Retrofitting an existing GIS, which is already in operation, is also possible. **For reasons of easy installation and commissioning, it is always recommended to equip new system installations of a gas-insulated switchgear with light sensors.**

The light sensor is required to optically monitor the condition of the system. Thus, various optical test components can be connected to it.

3.2.2. Fiber optic cable

As shown in Figure 4, the fiber optic cable serves as the transmission path of the system. It transfers the light from inside the switchgear to the evaluation electronic of the LIBO system.

Advantage of this technology:
The fiber optic cable is insensitive to electromagnetic signals and interference of any kind.

In order to protect the fiber optic cable from external mechanical and environmental influences, these are laid in compact and robust protective tubes.

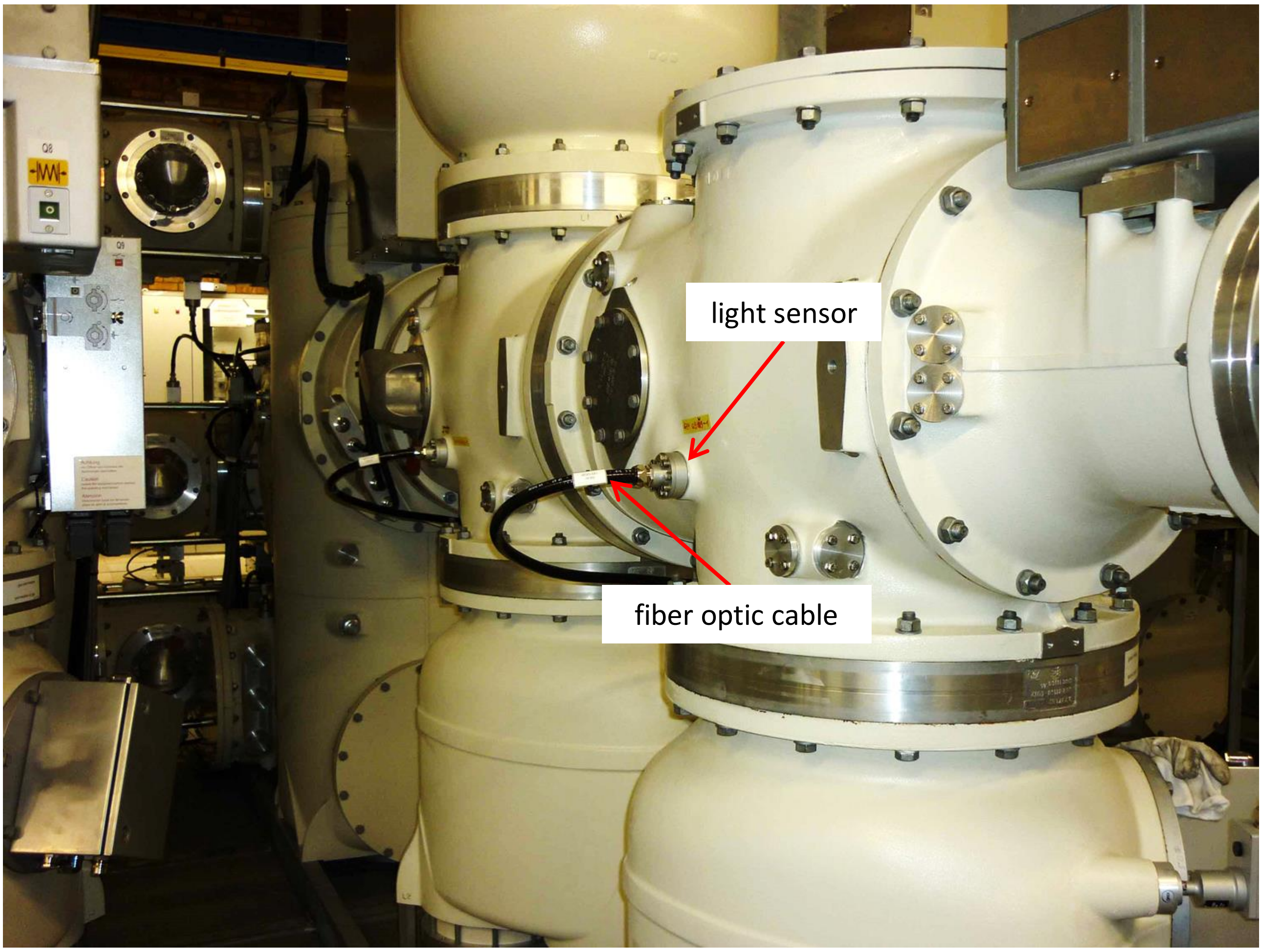


Figure 5: Light sensor with connected fiber optic cable and protective hose

3.2.3. Electronic

The third important component of the LIBO system is the evaluation electronic. In the case of an arc fault, the light signals are converted into electrical impulses.

These are evaluated by the electronics and display the location of the light phenomenon gas-compartment-accurate. In case of a power failure, these messages are stored and fast targeted switching measures are possible.

A communication channel is available as a single or group and collective message.

Passing on to a network control center is possible at any time via a serial communication.

Figure 6: Control cabinet with LIBO devices

Up to 40 fiber optic cables can be connected to an arc detection unit, which means that up to 40 gas-compartments can be consistently monitored. The system can be extended as required.

To ensure proper functioning, the LIBO system has a built-in self-test function.

3.3. Applications and versions

3.3.1. High voltage switchgears

Figure 7: High voltage switchgear

The system can be used in any gas-insulated switchgear from 60 kV to 1000 kV. The light sensors were developed together with participation of all the world's leading manufacturers of gas-insulated switchgears and can easily be connected to their gas-compartment

3.3.2. Medium voltage switchgears

Figure 8: Medium voltage switchgear

The LIBO system can also be used in gas and air-insulated medium voltage switchgears.
In compensated systems, a ground fault monitoring for early shutdown and damage minimization is possible.

3.3.3. Characteristics of the LIBO system

The LIBO system is characterized by the following features:

- gas-compartment-accurate location of accidental arcs
- fastest reaction possible, in the event of a fault
- rapid and well-targeted reactivation of the affected substation section possible
- allows for immediate reconnection of the non-affected substation sections - without any risk whatsoever

  → Faulty switching and their fatal consequences are avoided
- the system can be expanded and retrofitted as desired
- extremely resistant to external sources of interference such as:

  → UHF signals

  → cellular mobile telephony

  → air traffic

  → general electrical disturbing sources

  → general mechanical disturbing sources
- possibility of optical partial discharge diagnosis to test single gas-compartments for optical partial discharge phenomena (no reactivation or switching measures of the GIS necessary)
- with resistance or earth-fault compensation systems, an earth-fault can be switched off before a destructive short-circuit occurs
- Detection of the arc within milliseconds
- Essential for exact fault location during high voltage testing on the construction site
- Detection of flashovers under lightning impulse voltage test, switching impulse voltage test and alternating voltage test by exact location of fault location

  → short test and repair times

4. Earth fault detection system (ESK)

4.1. Introduction

The following article provides an overview of a proven substation protection concept.

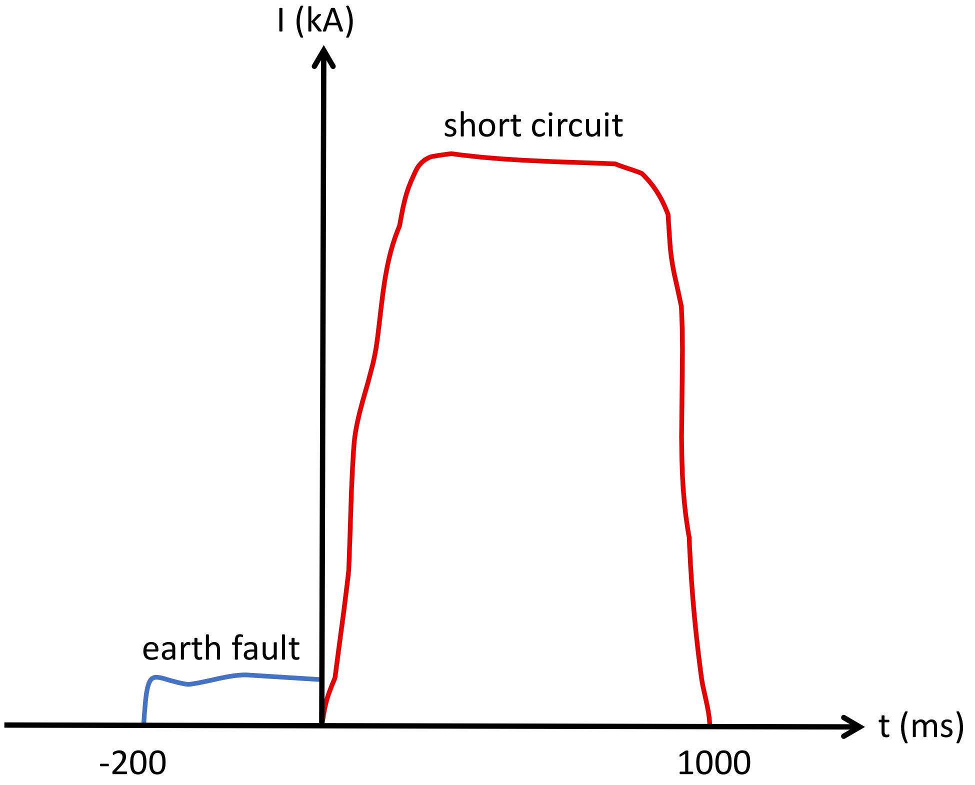


Figure 9: earth fault course

The greatest number of arcing faults in a medium-voltage switchgear are triggered by an 1-pole earth fault.

The 1-pole earth fault in the switchgear develops within a very short time into a 2 or 3-pole short circuit.

If it is possible to quickly and safely locate and disconnect this 1-pole earth fault in the system, significant damage can be avoided.

In the following, a concept will be presented that builds on the described basis and has now proven itself in practice.

4.2. Principle of operation

The functional principle is presented below, which essentially comprises the following two main components:

- the arc detection
- the earth fault or phase error detection (ESK)

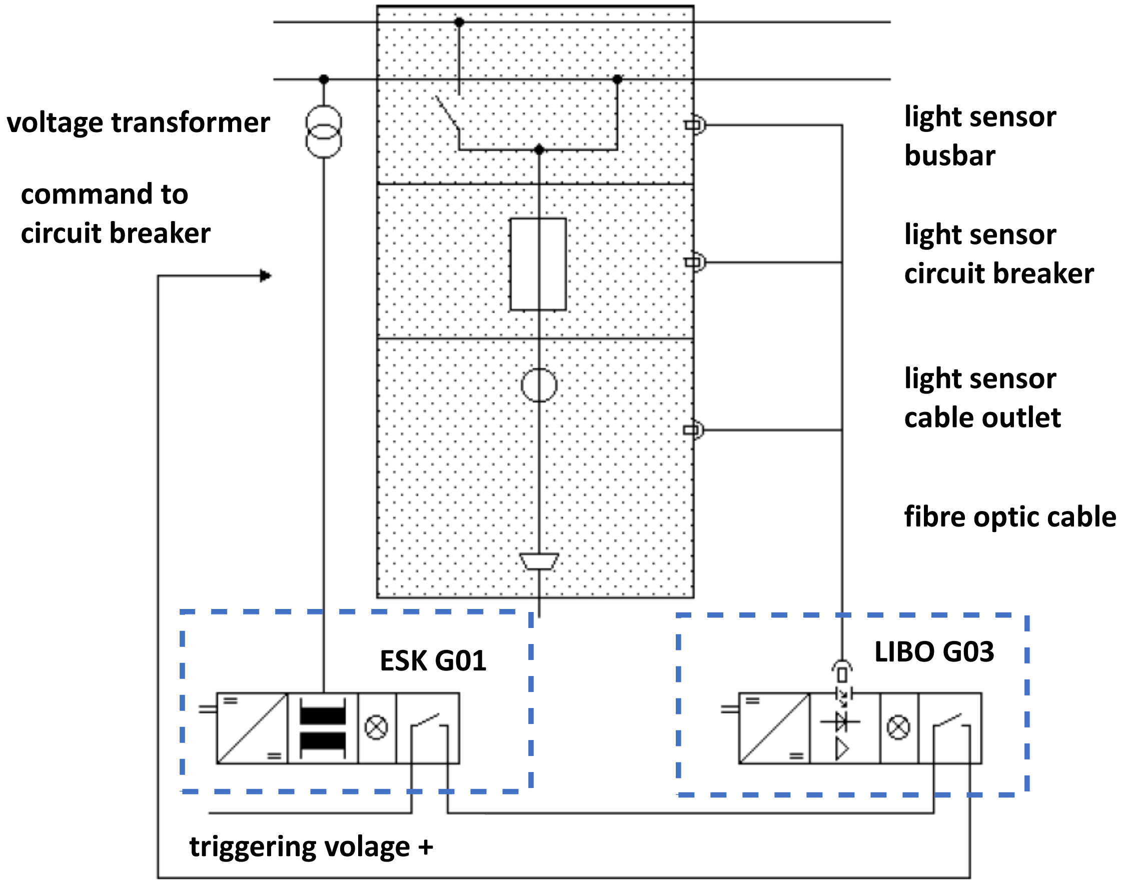


Figure 10: Principle of operation

Both the earth fault detection and phase error detection device, as well as the arc detection system, can together provide a contact **within 10 ms** that clearly detects the earth fault arc within the medium voltage switchgear.

Due to this very fast detection of a small arc inside the switchgear, the circuit breaker can be tripped and the fault can be released before a 2 or 3-pole short circuit occurs.

This reaction does not pass through the protection system, it is directly from the sensor device to the switchgear contact.

4.3. Operation of the earth fault or phase error detection

The ESK monitors the 3 phases of the switchgear. As soon as one or more phases deviate from the normal state, the downstream electronics generates the signal **"earth fault / phase fault"** in the form of a potential-free contact.

4.3.1. Reliability

Only the two signals "arc fault" (see 3. Optical Arc Detection System (LiBo)) and "earth fault / phase fault" together can cause tripping. This ensures optimum protection against false tripping and tripping of an earth fault outside the system.

4.3.2. Protective effect

Below, the effects of two earth faults are compared. Figure 11 shows a broken panel that has been disabled by the default protection.

In contrast, Figure 12 shows the effects of a ground fault, which could be shut down early by the LIBO + ESK system. The figure shows the faulty voltage transformer. After the VT was replaced the system could be put back into operation immediately.

Figure 11: Shutdown without arc detection and phase error system

Figure 12: Shutdown with arc detection and phase error detection system

4.4. Concluding remark

This concept guarantees fast and reliable detection of the fault within a switchgear. Because of the possible fast activation, the availability of the system is significantly increased. The damage impact on the system and the danger for the operating personnel are thereby considerably reduced.

5. Optical Partial Discharge System (OTEM)

5.1. System description

The detection of partial discharges at an early stage is an important part of the monitoring of gas-insulated switchgear systems in order to prevent failures, in the worst case the creation of an accidental arc.

An optical sensor can detect these partial discharge patterns. If such optically visible partial discharges occur within a GIS, the optical PD sensor detects them. Like a kind of "fingerprint", the optical partial discharge phenomena are shown for every gas-compartment separately. Depending on the type of fingerprint these patterns are differentiated into different partial discharge types and appropriate measures, can be taken.

Figure 13: OTEM on 400kV disconnector/earthing device

The optical PD module (OTEM) is simply mounted on the existing light sensor. Since this works as a passive element, it is insensitive to electromagnetic interference (EMC). However, the acquisition is also possible via standard inspection glasses on the GIS.

5.2. Theory of operation and components

5.2.1. components

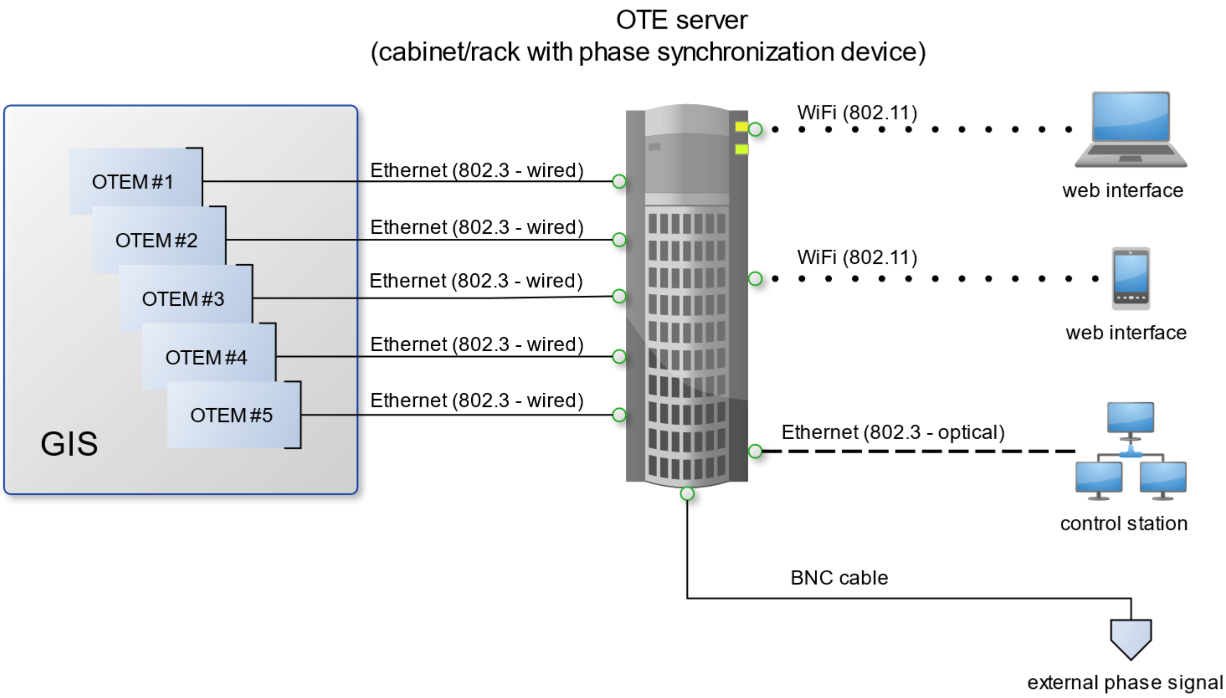


Figure 14: overview of the OTE system

The OTE sensor modules are connected to the OTE server by means of patch cables, through which they receive their supply (PoE) and can exchange data. Already in the OTEM, extensive data models are generated from the analogue raw signals of the sensors, which can be stored and archived on the OTE server. With the help of the web application developed by Vogl Electronic GmbH, the system user is able to view this data in many different ways. Furthermore, all sensor modules can be easily configured and individual and collective measurements can be started with the help of this application.

The phase synchronization for all OTEMs is done centrally on the OTE server. It is possible to feed in a phase signal externally, which is then used by the server for synchronization. If the synchronization is switched to internal, the server's power supply (AC) is used for synchronization.

The Web application can be used both on a PC/laptop and on the smartphone/tablet and does not need to be installed. The only requirement is a modern web browser (e.g. Google Chrome, Safari) and a connection to the OTE server. This can be established traditionally via patch cable or electrically isolated via WLAN (802.11) or optical Ethernet.

The system can be set up in two ways:

- stationary: Continuous monitoring of the entire system
- mobile: Temporary diagnosis of the condition of an entire substation/ medium-term monitoring of individual gas compartments

stationary operation

For fixed stationary operation, the OTE server is designed as a control cabinet (see Figure 15). All OTEMs mounted on the GIS are connected to the switch cabinet via patch cables. For larger 400kV systems, three fields are always connected to one switch cabinet, with the switch cabinets being interconnected.

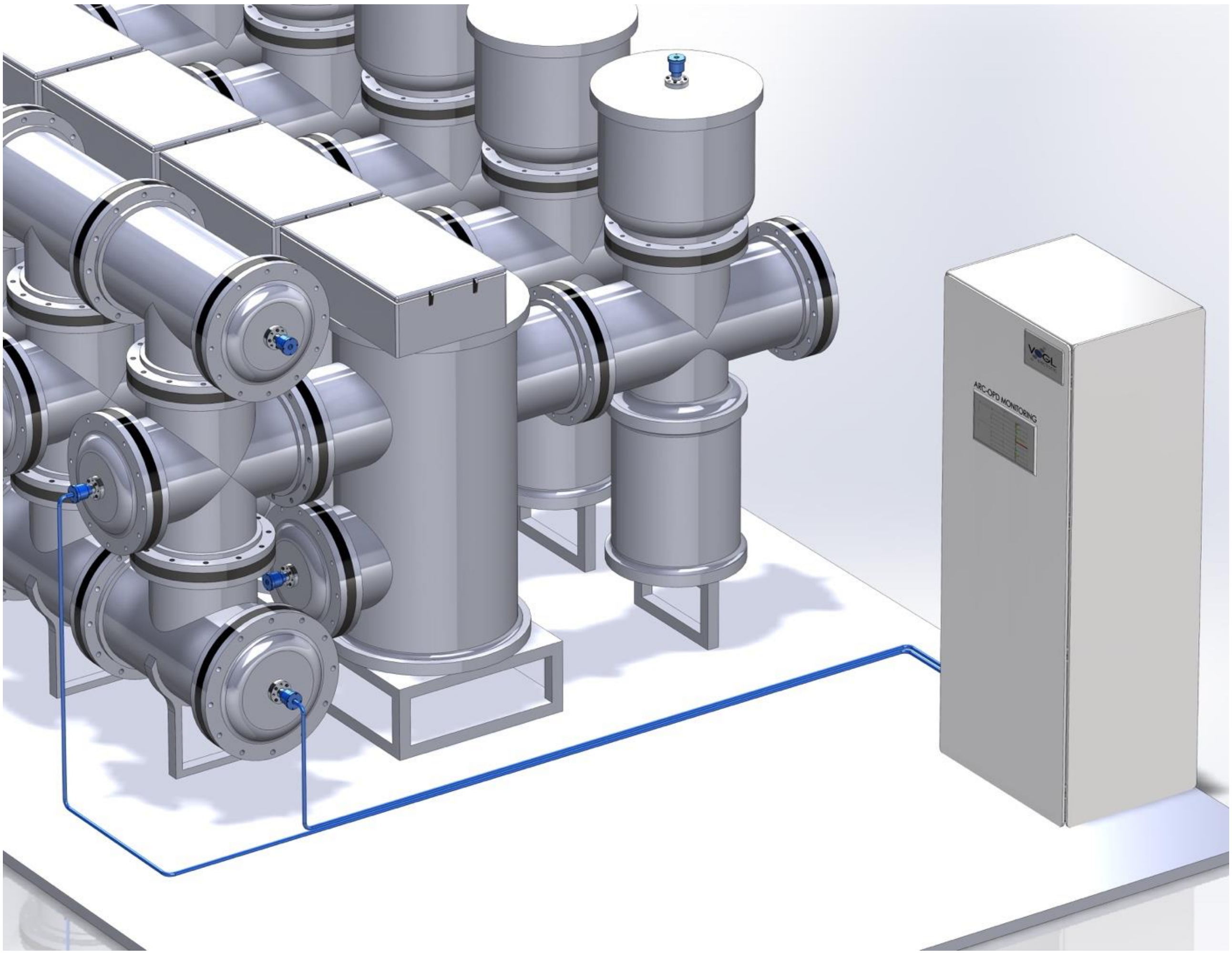


Figure 15: OTE-system stationary operation

mobile operation

For mobile operation, the OTE server is designed as a rollable rack to be transportable (see Figure 16). The OTEMs are connected to the rack using patch cables. This variant is suitable, among other things, for the continuous monitoring of individual gas rooms, a routine inspection of a plant or for high-voltage testing.

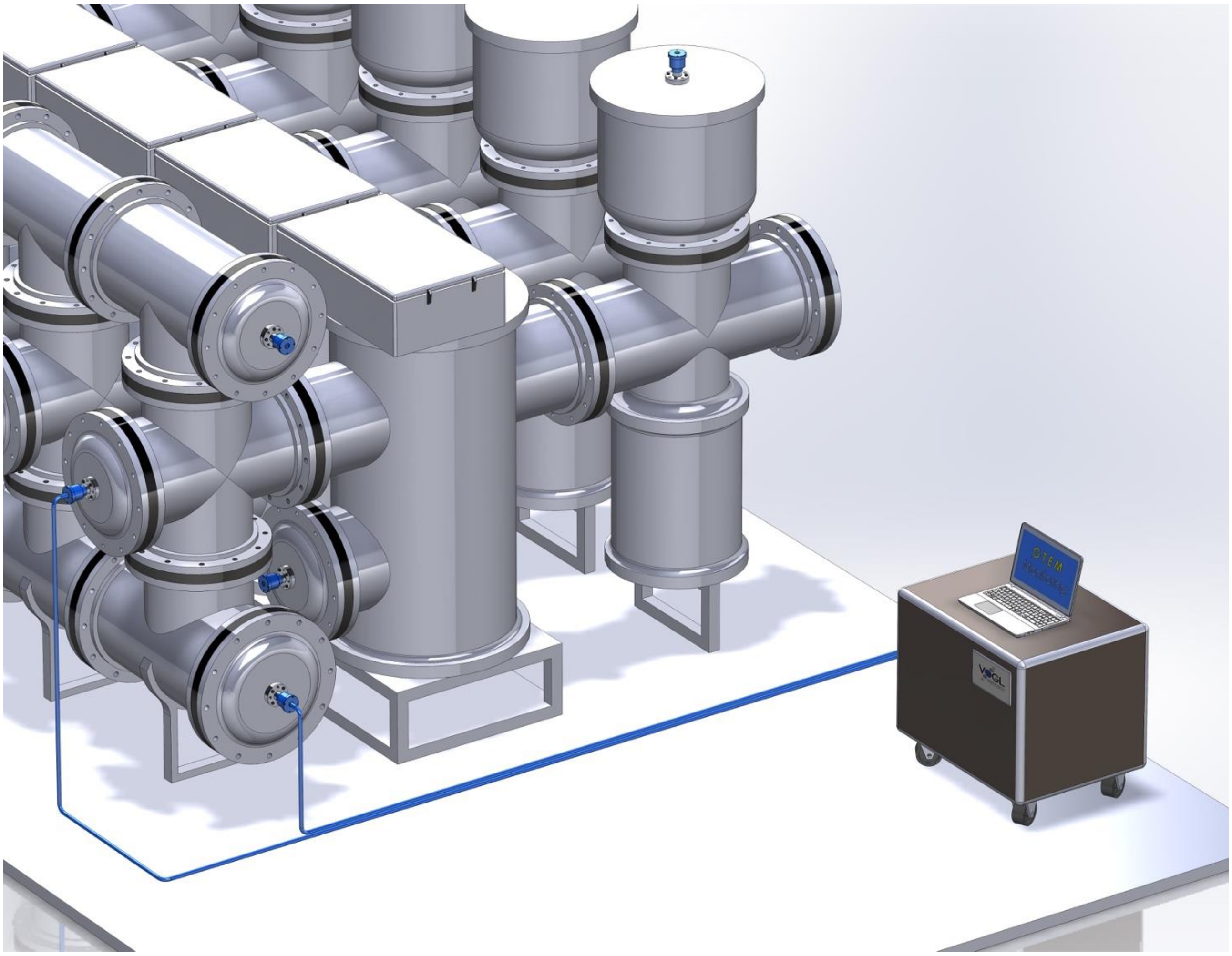


Figure 16: OTE-system mobile operation

5.2.2. Features

The system can detect optical partial discharge processes and display them accordingly. By synchronizing with the frequency of the high-voltage source, these optical signals can be represented in phase correlation and can therefore give accurate information about the type of optical partial discharge.

AC high voltage operation

The signals of the optical partial discharge can be detected and displayed as a PRPD pattern. Thus, the nature of the optical partial discharge source can be discovered and analyzed, and the optical partial discharge source can be distinguished as a particle on high voltage potential, ground potential, free potential or as a hopping particle.

DC high voltage operation

A special feature of the present system is that partial discharges can also be detected under DC high voltage conditions. As DC high voltage components play an increasingly important role, the optical partial discharge system can provide valuable and reliable information.

5.2.3. Examples of typical OPD fingerprints

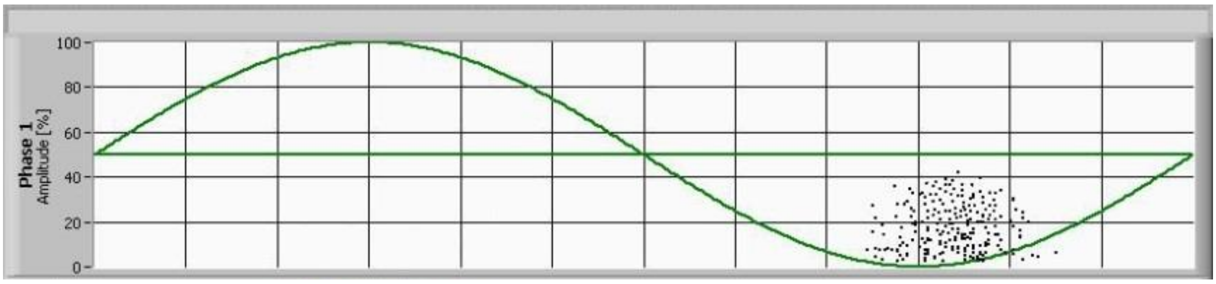


Figure 17: AC pattern fault location high voltage potential

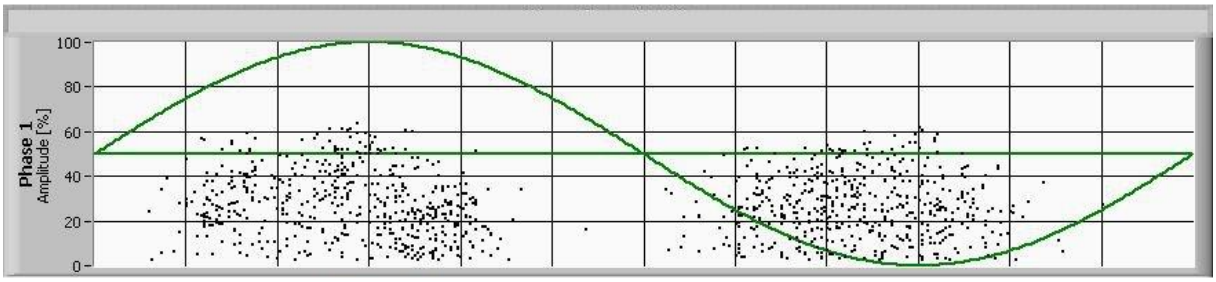


Figure 18: AC pattern fault free potential

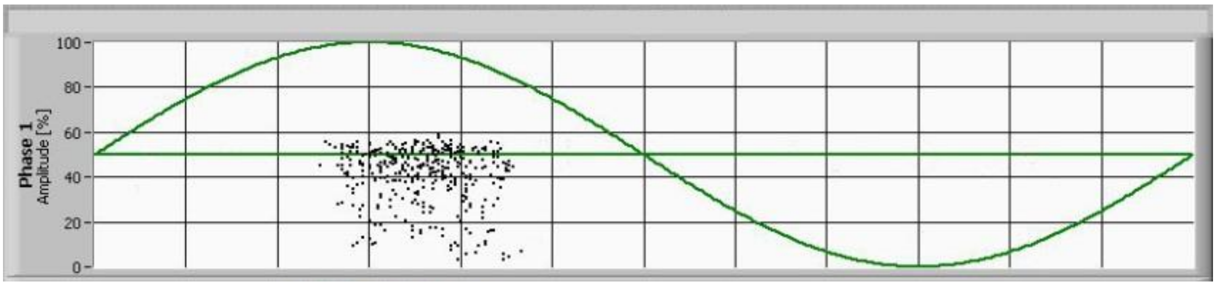


Figure 19: AC pattern fault ground potential

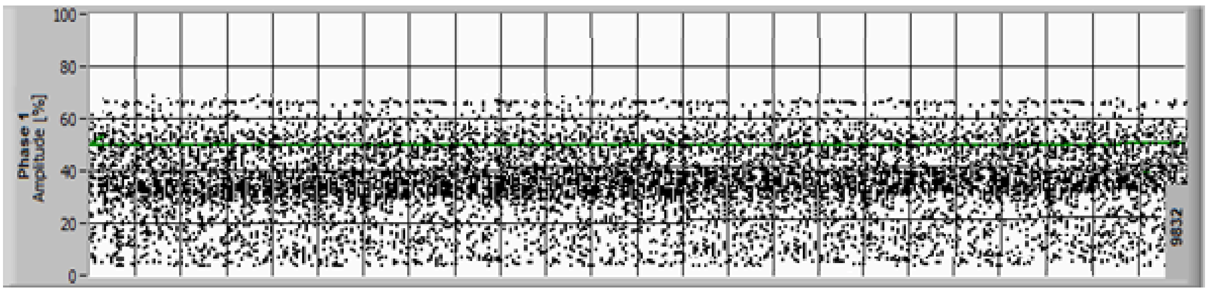


Figure 20: DC pattern fault DC-GIS

5.2.4. Evaluation

Mobile use

During the temporary condition check of the switchgear, a software which provides an overview of the gas-compartments (Figure 21) is used. Furthermore, a detailed display for determining typical PD pattern can be used (Figure 22).

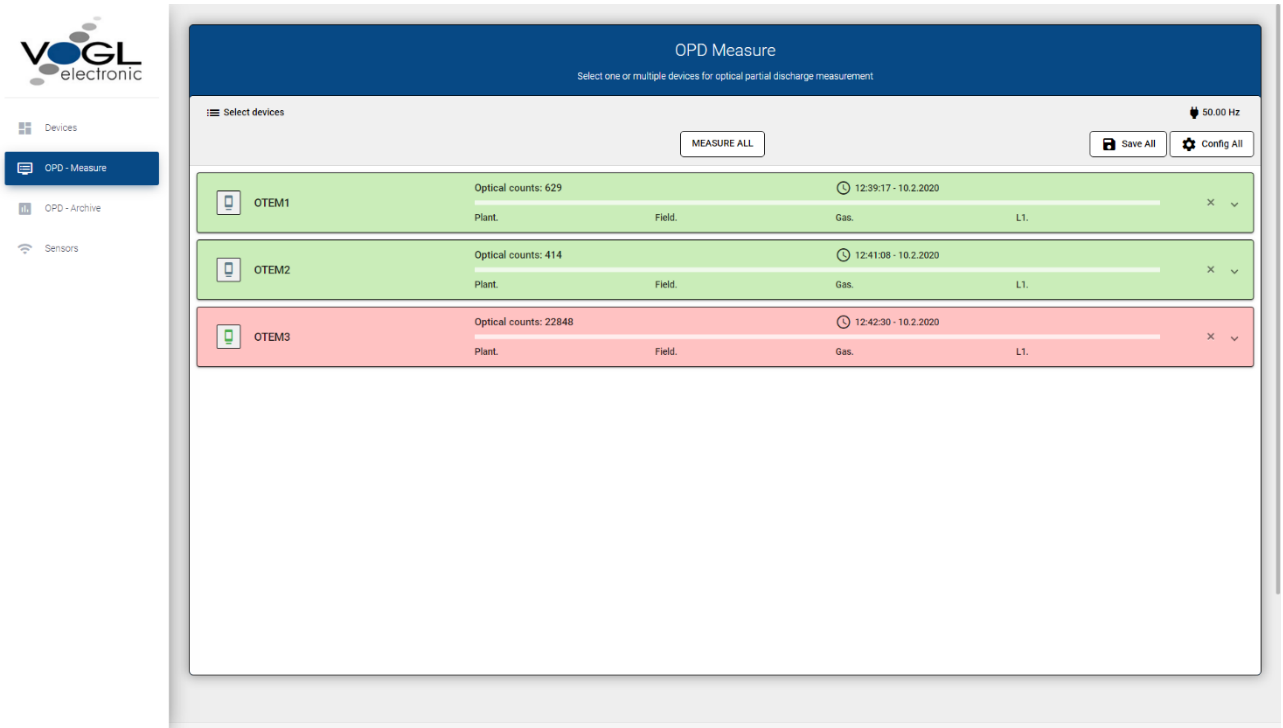


Figure 21: Overview of all sensors

Figure 22: detail view of individual gas-compartments

Stationary Use

If the system is permanently installed on the GIS to enable continuous condition monitoring, another web application is used. Changes over time in the PD pattern are very easily noticeable in the 3D view (Figure 23) and quickly localized in the substation overview (Figure 24).

Figure 23: example of a daily overview for statinoary use

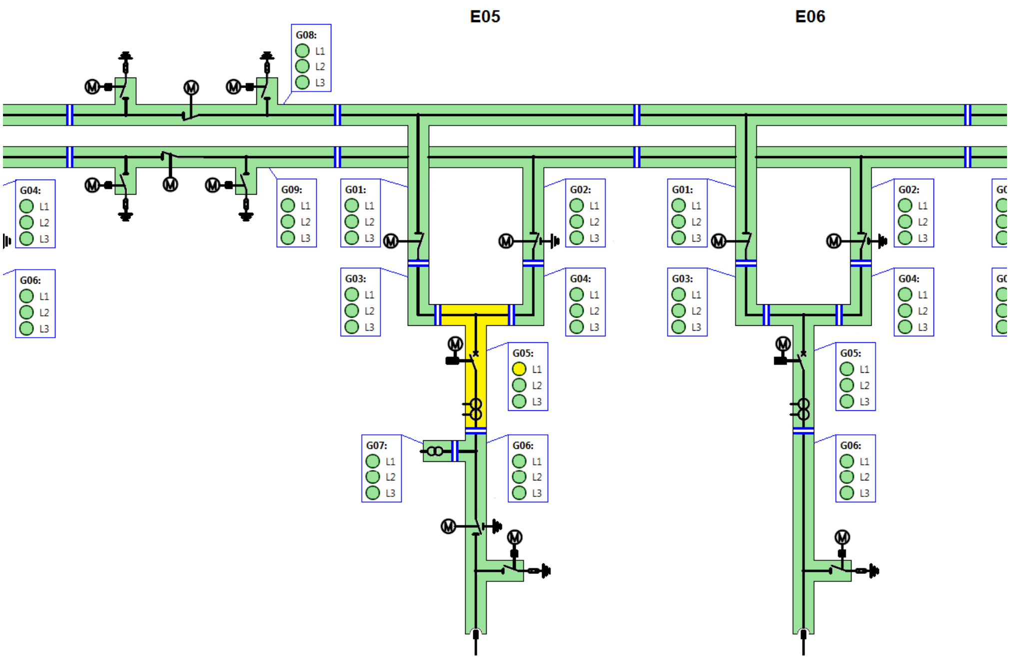


Figure 24: Overview in the single-line diagram

5.3. Characteristics of the OPD system

The OPD system is characterized by the following characteristics:

- Optical diagnosis is immune to external sources of interferences like:

  → Radio/-tv-frequencies

  → UHF signals

  → Cellular mobile telephony

  → Air traffic

  → General electrical disturbing sources

  → General mechanical disturbing sources

- Easy localization of the partial discharge sources via selective locating:

  → Information per gas compartment, if a light sensor or sight glass is available

- -PD diagnosis possible during switching operations to detect transient excitation of existing PD particles

- Specially designed for use with gas-insulated switchgear systems and high voltage test bays

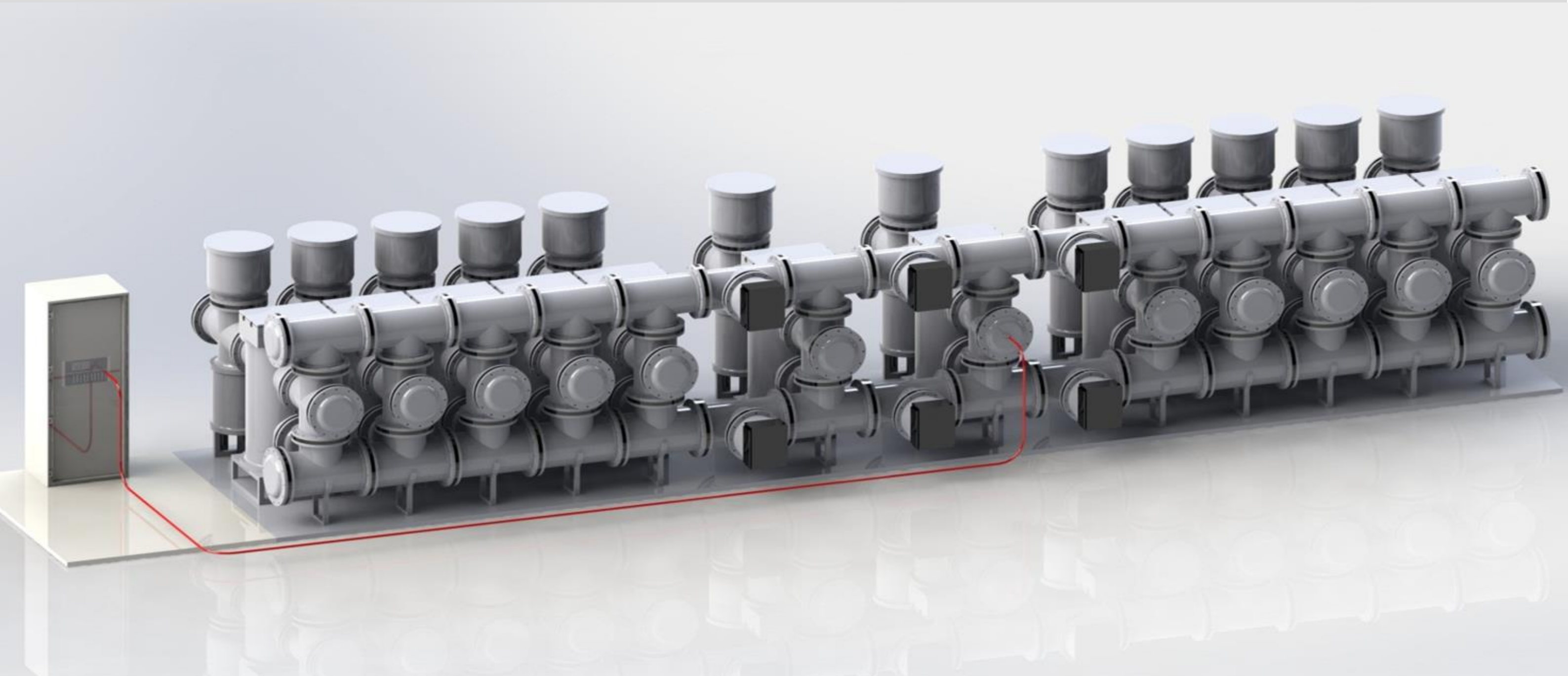
- Easy application: Just fix module to the light sensor. Switching in busbar or feeder is not necessary

Fault Arc Detection and

Optical Partial Discharge System

A contribution to securing our energy!

VOGL electronic



Vogl Electronic GmbH
Pieringer Stadtweg 1
94330 Salching
Germany

phone: +49-9421-55150
fax: +49-9421-5515–56

e-mail: info@vogl-electronic.com
www.vogl-electronic.com