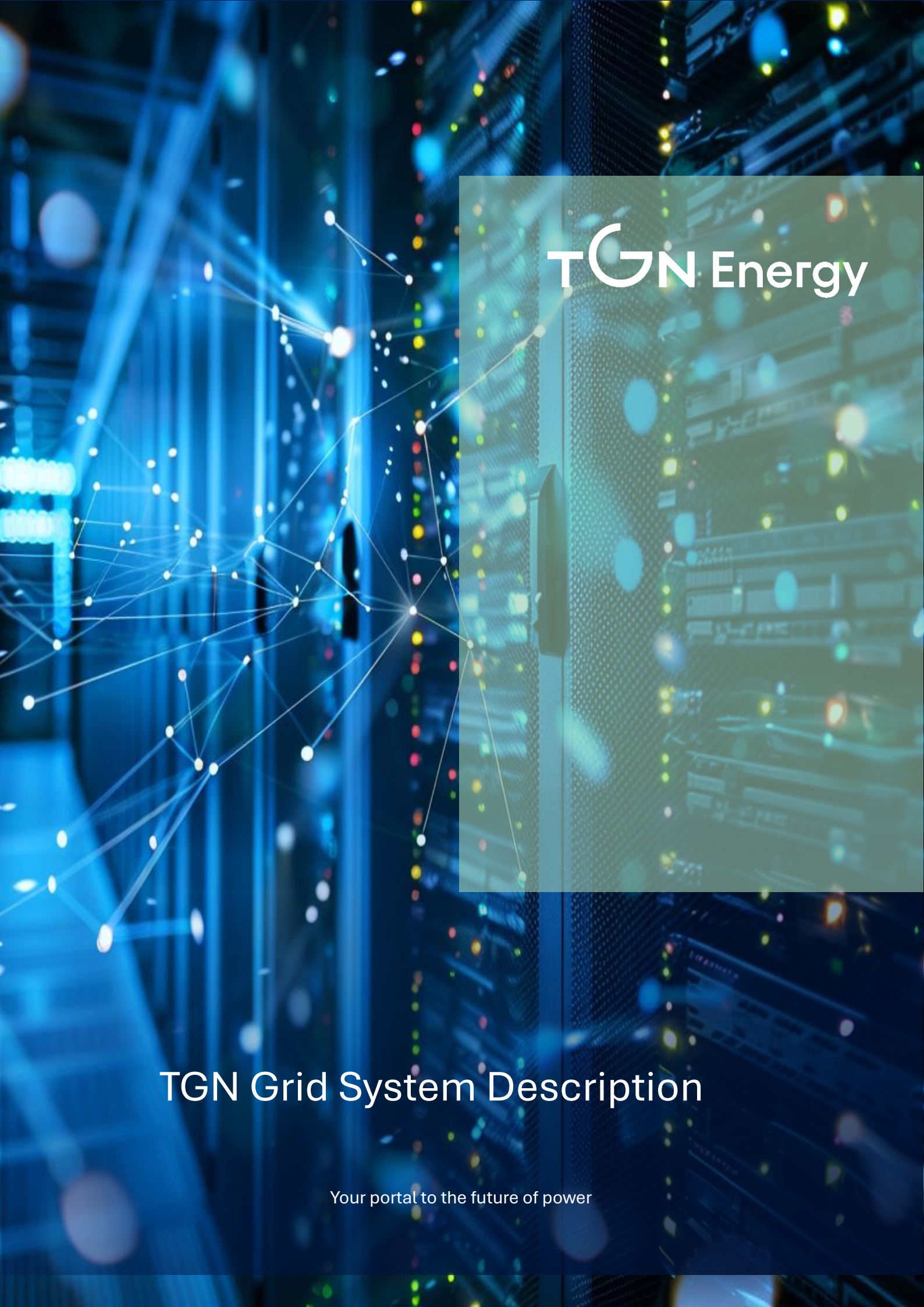

TGN Energy

TGN Grid System Description

Your portal to the future of power

Contents

1 System design

A TGN Grid is a smart power grid designed to give the owner or user full control over the power flow. This allows for oversight of energy utilization and facilitates more advanced interactions with the grid owner at both distribution (DSO) and transmission (TSO) level.

At the heart of the system is the TGN FlexControl. It has the ability to take control over any local energy source and **e**nergy **s**torage **s**ystem (ESS) and communicate the status to the cloud-based platform TGN Aggregate. From there, the user can monitor every aspect of the power flow and get detailed reports on status and operations.

A TGN Grid can contain energy production systems and ESS of any type, number, and size. In addition, active load shedding can be performed on loads that permit regulating; typically, thermal equipment or airflow equipment such as HVAC systems.

Figure 1.1: Schematic image of the flexibility of a TGN Grid.

1.1 TGN FlexControl

At the heart of every TGN Grid is a TGN FlexControl. This is a command-and-control hub for control signals, data collection, calculation and communication with the outside world. Energy systems such as solar cells and batteries can be controlled directly from FlexControl, either autonomously or by manually setting the operational policy.

1.1.1 Communications protocol

FlexControl is designed for maximum flexibility and communication with all kinds of energy equipment relevant to a local grid. As standard, FlexControl communicates with external equipment via Modbus TCP/IP, RS-485 and Modbus RTU. Adjustments can be made for communication via other protocols, provided they maintain adequate operational security.

1.1.2 Cyber security

No component of TGN FlexControl communicates directly with the outside world and will therefore be highly resistant to cyber-attacks. All communication takes place via secure communication lines to a secured cloud terminal where signals are controlled and forwarded to TGN Aggregate.

TGN FlexControl uses the IEC 62443-3-3-3 security standard and implements requirements for Cyber security essential (SP1) that are requirements from DNV for IT security for IoT devices on marine structures, such as oil platforms and sub-sea installations.

1.2 TGN Aggregate

A TGN Grid is managed from the TGN Aggregate platform. This is available on all types of computers and smart devices with access to the internet since it is operated as a cloud service with a web browser interface. Each user gets their own customizable access area, where data from TGN FlexControl is presented together with data from externally relevant sources. Weather data, electricity prices, etc. are displayed directly in the interface for each location the user has access to.

1.2.1 Aggregation of resources

TGN Aggregate collects data streams from all locations and components connected to the system. This enables the collection of large quantities of smaller resources, such as batteries, in order to provide total resources for trading in the reserve power market.

1.2.2 Systems management

Via the cloud platform, the user can see the location of all systems on a map and get a quick overview of the status of all systems. Error messages and alerts will pop up in the platform to notify about possible necessary actions. The system also produces reports on demand for reporting and documentation of the system operation and what activities the systems have engaged in.

1.3 External components

A TGN Grid will contain external components. This could be solar cells, battery banks, hydrogen storage, wind power installations, etc. It will be possible to document the energy flow to and from such components and control the operation of the individual components through TGN FlexControl.

2 System description

2.1 System integration

Solar cells and other local production facilities will normally be connected to a main switchboard, in connection with the main intake, so that energy can be sent directly to the grid or used throughout the electrical system. The same switch-on will normally occur with batteries and other forms of storage, for the same reason. The energy flow will be controlled by direct regulation of voltage in inverters and transformers to the various systems. This is actively regulated by TGN FlexControl's control signals to the various systems.

By using the calculation capacity of FlexControl, intelligent use of energy can be achieved. Power requirements at different times of the day, power reduction when charging vehicles or other system operations can be directly supported by TGN FlexControl.

2.2 System operations

2.2.1 Peak-shaving & Demand Limitation

Most types of energy users with high energy consumption will have power peaks. It can come from the start-up of machines, simultaneity in equipment operation, or the sudden activation of large spenders such as electric car chargers. In *Peak-Shaving* mode, TGN FlexControl will use available resources to compensate for the power draw, so that the increased energy use is taken from alternative sources to the grid. It can be batteries, hydrogen storage, or other forms of controllable energy sources.

A more active variant of this is called *Demand Limitation*. This means that the system has set a maximum limit for intake from the power grid and will continuously try to compensate for all consumption above this limit. If the storage is dimensioned correctly, this can help reduce grid tariff effects.

2.2.2 Intra-day Trading/Arbitrage

The electricity price is established every day around lunchtime, for the next day. This means that the price is known at all times, at least one day in advance. This opens up the possibility of purchasing energy from the power grid for storage, and then selling off again when the price has increased.

2.2.3 Reserve power market

All energy produced at any given time must also be consumed. If more is produced than what is consumed, the frequency will increase, and decrease if the production is less than the consumption. The power grid is vitally dependent on maintaining a constant frequency – 50Hz, at all times, which places high demands on matching between production and consumption.

Traditionally, the huge rotating wheels in hydroelectric plants, coal-fired power plants or nuclear power plants will have enough momentum to not slow down or accelerate (and thus change the frequency) when the matching is not perfect. Modern inverters that

transform direct current into alternating current do not have this capacity. With a sharply increasing share of renewable energy in the systems, and which also produce in a non-consistent manner, a need arises to actively compensate for differences between production and consumption. This is handled by the reserve power market.

TGN FlexControl has the capacity to control power out of energy storage when the frequency rises or falls outside any given limit values. This capacity can be sold to balance managers in the free market, thereby bringing income to the system owner and increased stability in the power grid.

TGN FlexControl offers participation in the regional TSO reserve power market. This is done in cooperation with balance responsible parties that conduct trading. In a similar fashion, TGN FlexControl also offers connection to local flexibility markets such as Nordflex/Euroflex, though this may not be available in all regions.

2.2.4 Active Islanding

In the event of a loss of supply (LoS) from the power grid, inverters and other potential power producers in the local grid will be disconnected. This is necessary since such resources will not be able to operate the entire power grid themselves but will be able to generate enough power to injure personnel working on the power grid for repairs or maintenance. The disconnection function is often called *anti-islanding* since it is intended to prevent local resources from creating energy islands.

Active islanding will disconnect the overlaying power grid and use local resources to re-establish the grid locally. This is done in a highly controlled fashion and will secure the supply in the local grid in the event of a failure. A TGN Grid can be set up with Active Islanding so that batteries and other resources are actively used to secure the supply in the system. This can allow enough time for a controlled shutdown of an industrial process or secure critical infrastructure until the power grid has been re-established. Disconnection and connection to the overlaying power grid will take place completely autonomously and virtually seamlessly.

N.B. Active Islanding requires specialized equipment and is not supplied as a standard feature.

2.2.5 Reactive load compensation

Reactive load occurs when heavy and energy-intensive loads create a shift between applied voltage and current. Reactive load will always occur to some extent and can become a problem if it becomes large. Therefore, a fee is imposed (in some countries) by grid companies (DSO) in proportion to a consumer's reactive load.

A TGN Grid can compensate for reactive load by using stored energy, applied to the grid with the correct counter-shift. Thus, such fees can be minimized and negative effects on the power grid avoided.

2.2.6 Electric car charging

Through external interfaces, via Modbus TCP, FlexControl can handle EV chargers and mitigate charging power peaks for EV charging. Parameterization of maximum permissible power will be handled in the user interface by using the battery to compensate for power imports from the mains.

2.3 User interface

2.3.1 TGN FlexControl

TGN FlexControl is only managed by authorized personnel. This can be done directly from the control cabinet HMI (Human Machine Interface) or remotely from a secure connection via the internet. Here, the operation of the system can be determined, controlled, and overridden if necessary. System tests and maintenance can also be administered here. Detailed operational instructions can be found in the TGN FlexControl Operations Manual.

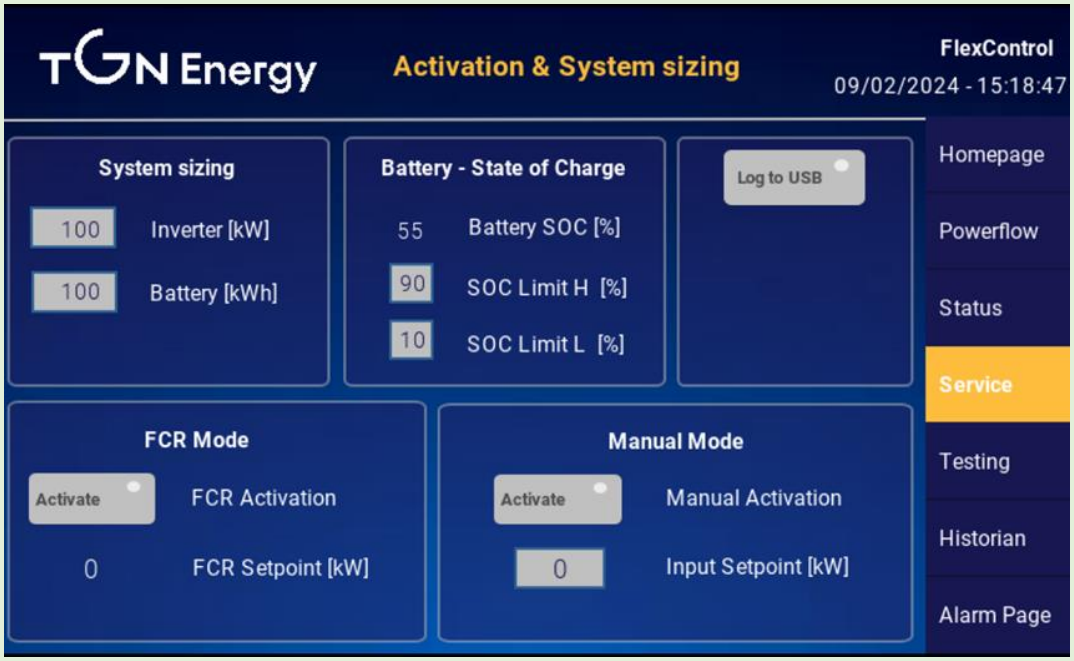

Figure 2.1: Home screen of the TGN FlexControl HMI.

2.3.2 TGN Aggregate

TGN Aggregate can be accessed through any web browser and presents the user with an interface as seen in figure 2.2. Here, users will always be presented with updated systems information as well as other relevant information. Local energy price, carbon emissions, trade planning schedule and much more, is presented in an easy-to-understand manner, to enable any user to grasp the status of the system.

Each system the user has access to is presented either on an interactive map, or in a list of sites. This makes it possible to quickly get an overview of the operation of all systems the user has access to, anywhere in the world.

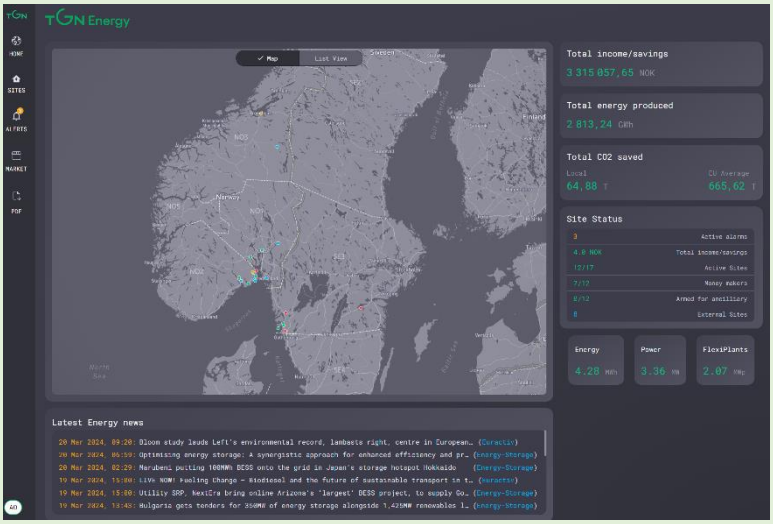

Figure 2.2: Landing page of TGN Aggregate with overview of all total ystems data and locations of all systems on a map

2.4 Systems communication

TGN FlexControl will actively report the system's status to TGN Aggregate, along with calculated figures for the results of the activities performed by the system. Everything from system status and error messages to earned income or savings and CO_2 savings.

An installed TGN FlexControl can be set to send regular status reports by e-mail to users or relevant authorities if desired. This enables running evaluations to be simplified and save time and effort on information gathering and analysis.