ADVANCED PLANNING SOLUTION FOR OPTIMUM ISLAND NETWORK DESIGN AND OPERATION

Off-grid energy supply

At a glance

Island network and autonomous microgrids combine essential opportunities for distribution sources but pose special challenges in system operation as they are especially vulnerable to system instabilities. Siemens Power Technologies International (Siemens PTI) can help find an individual solution adapted to the needs of any island network, to increase the stability of the system and thus avoid system outages.

Siemens PTI supports customers in the following tasks:

- Evaluating an independent energy supply against a connection to the main grid
- Defining the specific optimum between technical and economic feasibility
- Substituting expensive generation units by efficient sources depending on the specific availability
- Detecting the causes for power supply faults and providing state-of-the-art simulation tools from the PSS® product suite to model system performances and identify possible solutions
- Considering voltage and frequency control aspects and implementing the changes which will increase the stability of the island network

The challenge

Island networks, like the bulk power grid, generate, distribute and regulate the flow of electricity in island operation, and are also used for military bases, industrial applications, airports, hospitals, colleges and business campuses, at the utility distribution level and for rural electrification in developing countries.

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Due to their size island networks react more critically to dynamic performances than networks which are connected to the main grid.

In parallel, distributed energy resources (DER), like photovoltaic and wind power, perceive more and more importance to the energy supply portfolio within off-grid energy systems. While decreasing generation cost of DER provide the potential to increase the economical performance of these autonomous energy systems, their fluctuating in-feed character causes additional challenges in operation and system stability. Challenges like deviations from predicted generation profiles, as well as voltage drops or increases, require new planning and operational principles for system operators. To ensure optimal design and operation of island networks, there are many questions that need to be answered such as:

- What level of control is required to maintain power quality and reliability?
- How can I maintain continuous power supply for critical facilities during a natural disaster?
- What quantity of non-dispatchable vs. dispatchable DER is best?
- What are the optimal locations for the DER?

In case of connection to the main grid:

- Is it cost effective to build a connection to the main grid?
- What are the parameters for the decoupling and protection of the network in the event of falling into isolated operation?
- What is the reaction of the island grid regarding transient stability, voltage recovery and frequency?

Our solution

Siemens PTI is a global provider of independent, technical consulting services for power generation, transmission and distribution systems. Our power system consulting team has extensive experience in determining the best island network design possible from a technical and economic perspective. Our analysis accounts for optimal DER location, size, dispatch mix and technology, while considering protection coordination, power flow, reliability improvement, cost, and interconnection requirements.

Siemens PTI has developed a holistic planning approach that assists our customers with island network studies on any electrical network topology, regardless of size, voltage level or location, and provides detailed analyses ranging from strategic steady state power flow simulations to dynamic and transient studies.

Strategic techno-economic evaluation of island grids

Based on a given electrical network, selected generation and demand response (DR) participation, the island network study calculates the following:

- Potential N-0 thermal overloads and/or voltage violations
- Estimated cost of operation based on the power flow results (accounting for capital costs, fuel costs, O&M, cost of money, heat savings from CHP)
- Reliability indices, i.e., System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI) and Expected Energy Not Served (EENS)
- Priority-based economic DER dispatch

The simulations deliver detailed information about the operation of the available generation resources, like fuel consumption or number of starts and stops of thermal power units, number of cycles of battery storage units or the share of renewable energy sources to the total energy consumption of the energy system.

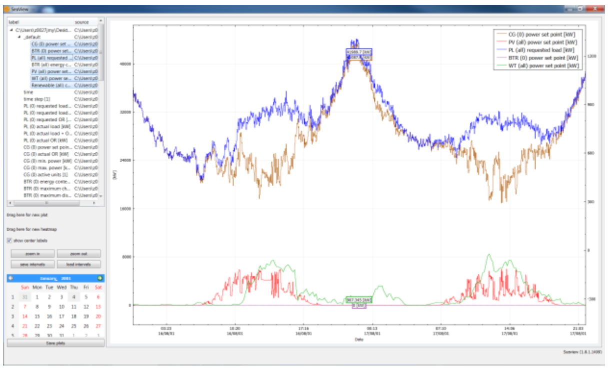

Figure 1: Exemplary dispatch simulation of island network

In addition, the simulation delivers financial results considering the capital and operational expenditures of the selected generation structure on the basis of the specific composition and interaction of different generation resources. In consequence, financial Key Performance Indicators (KPIs), like Levelized Cost of Electricity (LCoE), Return on Investment (RoI) or Net Present Value (NPV), can be derived for the evaluated scenarios.

Dynamic evaluations

As island or off-grid networks are extremely sensitive to faults, the dynamic behavior of the system has to be evaluated to ensure system stability.

A power system fault can be detected by means of suitable indicators. These indicators can be current, voltage, power, phase, frequency or frequency gradient. Simulations are used to model all power system faults and to determine the response of the generation (and storage) units in terms of stability, voltage recovery and frequency. This makes it possible to derive parameters for protecting electrical equipment with regard to size and time, so that the stability of the generators and voltage recovery are ensured when there is a transition to isolated operation.

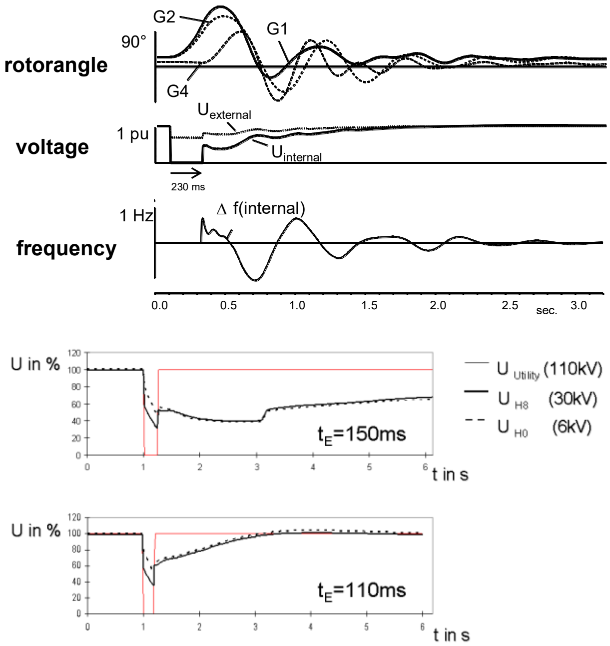

Figure 2: Generator stability and voltage recovery after short circuit

As the outage of a generator is the most critical fault, it must be compensated with the reserve of the other machines or by load shedding. In this case, the operating conditions and technically realizable possibilities need to be synchronized to ensure a continuous and reliable operation. Load shedding can be activated by signal in reaction to a generator outage or by frequency reduction, depending on whether fast frequency stabilization is required. Generator outages not only lead to a lack in active power, but in reactive power, which, among others, can cause the voltage to collapse.

Additionally, the demand for reactive power can be critical after short circuits, since motors or groups of motors have to accelerate again and therefore have a higher demand for reactive power at longer fault times, which cannot be supplied by the generators in the isolated network. Based on the evaluations the system can be coordinated and the measures adjusted (reserve, disconnection of generators, protection, disconnection of loads, storage etc.).

Benefits for the customer

By performing network structure development and dynamic studies for island networks, we can provide several benefits to our customers:

- Identification of weak points in the existing network and development of optimal network concept
- A load management system for the control and design of each operation mode as well as interconnections for an automated adjustment of the operation and start-up of generators ensure smooth and secure operation
- Verification of an appropriate network performance by analyzing defined KPIs and development of a detailed transition master plan ensuring optimal investment utilization

The investment in a strategic network planning study is very low compared to the capital and operation costs that can be saved by an optimal development of the network. With Siemens PTI's industry leading expertise and software, we offer a broad spectrum of island and off-grid network studies based on a thorough understanding of processes and aligned with the need for enhanced planning capabilities.

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