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A proposed power control solution for industrial application in decentralized energy production

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Abstract

Communities and industries across the globe depend on decentralized power generation to ensure the availability and security of supply. As the world moves toward decarbonization, energy generation systems are increasingly turning to small-scale turbines or engines operating on hybrid solutions with renewables as a cleaner, intermediate step toward a truly sustainable future. The infrastructure of the main electricity network in Albania is very problematic and about 90% of the energy is produced by hydropower plants, increasing the dependence on rainfall. Based on this problem, in order to have the independence of the electrical energy of the industry from the main electrical energy network in the country, in this paper is proposed a solution of energy control for decentralized energy production. This automated solution interconnects groups of distributed energy resources and loads at a defined electrical boundary. It can operate in either island/isolated mode or networked mode. In a system consisting of a generator and photovoltaic plant, this automated solution guarantees minimum fuel consumption by maximizing PV penetration without compromising minimum genset load requirements. This decentralized system of energy resources is based on IIoT, helping to develop smart cities. Decentralized control support identifying and control of important challenges for our unstable energy grid. Beyond the technical hurdles, our energy grid also needs a new paradigm for resilience, protecting against natural disasters and cyberattacks.

Introduction

For decades, power grids have been structured in a hub-and-spoke model, with a few large, centralized power-generating plants providing electricity to a huge consumer base connected via long transmission and distribution lines. The idea was that the larger you build the plant, the more efficient the electricity system. For a long time, that logic held true. But with the urgent need to pursue decarbonization, the large increase in intermittent renewable energy on the grid, the still-expensive nature of energy storage, declining costs of decentralized generation, and the need for greater grid resiliency, decentralized power generation is increasingly recognized as a crucial tool during the energy transition [1-2].

Decentralized energy systems provide promising opportunities for deploying renewable energy sources locally available as well as for expanding access to clean energy services to remote communities.

The paper proposes a power control solution in a decentralized energy production system. The paper proposes a power control solution in a decentralized energy production system. This is given through a concrete application of the industry's need for energy production, creating dependence on the network in the country [3]. In the exciting system that the factory has to produce electricity consisting of a generator and the main energy network, it is proposed to integrate a renewable source such as a photovoltaic plant and also a controller for power management.

The system proposed in the paper offers a reliable, fully integrated and optimizing solution between sustainable power plants and generating power plants. The system is designed for green applications and includes controllers that can interface with PV inverters and other power source controllers. With the usage of an intelligent and flexible generator controller, power generation becomes more efficient without additional climate impact. With a highly configurable electric switchboard, power goes where it needs to go and ensures uninterrupted uptime.

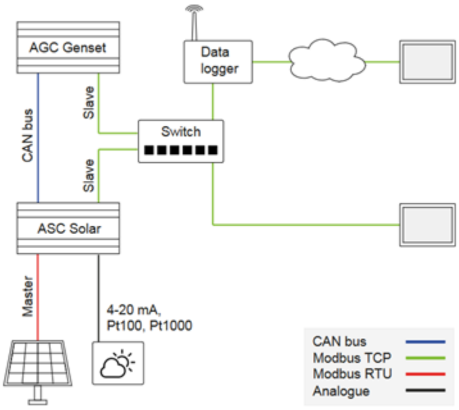

Figure 1. Hybrid energy system

Decentralized energy system

A decentralized energy system is characterized by locating energy production facilities closer to the site of energy consumption. A decentralized energy system allows for more optimal use of renewable energy, reduces fossil fuel use and increases eco-efficiency [4]. A decentralized energy system is a relatively new approach in the power industry in most countries. Traditionally, the power industry has focused on developing large, central power stations and transmitting generation loads across long transmission and distribution lines to consumers in the region. Decentralized energy systems seek to put power sources closer to the end user. End users are spread across a region, so sourcing energy generation in a similar decentralized manner can reduce the transmission and distribution inefficiencies and related economic and environmental costs.

Hybrid energy system

A hybrid energy system combines multiple types of energy generation and storage or uses two or more kinds of fuel to power a generator. A hybrid energy system is a valuable method in the transition away from fossil fuel-based economies [5-6]. Particularly in the short term, while new technologies to better integrate renewable energy sources are still being developed, backing up renewable generation with conventional thermal electric production can actually help expand the use of renewable energy sources [2].

Hybrid energy systems can capitalize on existing energy infrastructure and add components to help reduce costs, environmental impacts, and system disruptions. Planning a hybrid electricity system has a market focus rather than a technology focus: the priority is to choose a mix of energy technologies that is the most efficient and reliable way to meet users' needs. The proposed solution in the paper maximizes renewable energy penetration which can satisfy the energy demand and maximize the system energy efficiency as illustrated in the Figure 1.

In each operating mode, the solar controller automatically maximizes the stable energy penetration, depending on the total load demand on the hybrid plant, without compromising constraints such as the minimum generator load demand. In off-grid operation, the system provides a minimum generator load constraint that lowers steady power penetration if PV production is compromised. This ensures a certain amount of load on the generators, eliminating the risk of reverse power situations and the problems of dirty burning and exhaust.

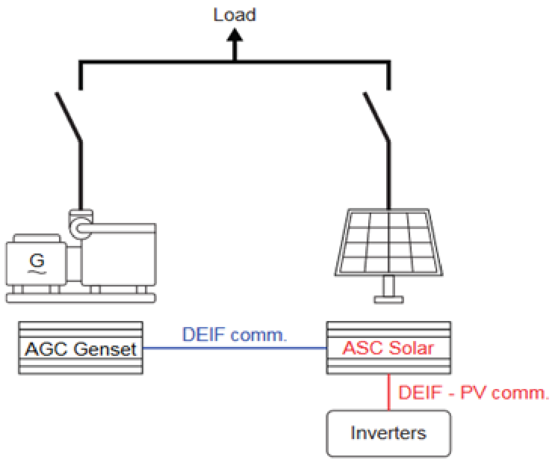

Figure 2. Communication between PV, generator and controller

Results and Discussion

In the proposed solution, consisted of a generator and a PV system, a controller has been integrated for power management based on the consumption of the factory.

Through the controller we manage to realize the following processes for each hybrid resource:

- PV plant: P and Q control, Control PV breaker, Inverter communication.
- G-set: Governor Control, AVR control, Control genset breaker, ECU communication.

Controller communicates with the inverters through a gateway device-data manager as shown in. Controller communication with the PV uses a Modbus RTU protocol. The controller is the master and the inverters are the slave [5]. As it is presented in Figure 2 from the data obtained in real time of the energy flows in the factory, through the controller, energy management was realized based on the consumption of the factory.

In the Figure 3 is presented the case of system operation, when there is no network and the factory's consumption needs are met by PV and the generator according to the algorithm set in the controller. So, by receiving information on the consumption of the factory, energy management is done, making maximum use of the power from the PV plant, while the generator operates with minimum operating conditions as presented in the simulation in Figure 4.

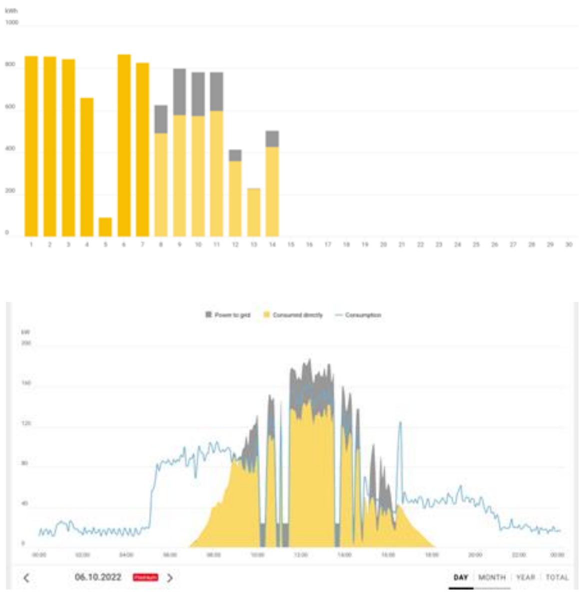

Figure 3. Energy data received from PV, generator and grid

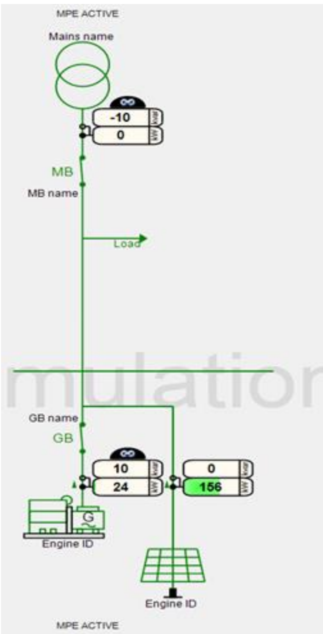

Figure 4. Simulation of the system in the controller

Institutional Challenges

- State-controlled electricity markets hamper the development of a decentralized energy system because distributed generation encourages myriad actors to become power producers.

Technical Challenges

- If not properly planned, large-scale deployment in distributed generation may result in the instability of the voltage profile.
- Emerging technologies, such as smart grid, renewable energy, and energy storage, will require the operation criteria of the whole power system to be redesigned and modified.

Conclusion

Our hybrid power solutions combine renewable energy sources, the generator, and the main power grid in a hybrid power plant or microgrid. Intelligent automated solutions for energy management using IIoT enable the development of smart cities. Through this paper and the results obtained in the sections above, we reach the conclusions that such power control systems in decentralized energy production systems have the benefits:

- Rural electrification: Because grid integration of distributed generation and storage requires major technical upgrades, countries in the region can focus on distributed generation for rural electrification – either through off-grid or mini-grid systems.
- Increases in the share of renewable energy: A decentralized energy system is designed to accommodate many energy sources, including renewable sources with intermittent production, such as wind and solar. Distributed generation, demand management and storage can all facilitate increased inflows of renewable generation.

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