Microgrid control ethiopia

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The growing demand for electricity, concerns over environmental emissions, the high risk of fossil fuel depletion, and the challenges of grid expansion to supply remote villages due to economic and technical constraints make renewable energy source (RES)-based microgrids (MGs) the most effective solution for electrifying both rural and urban areas. In addition to providing lighting, access to electricity plays a crucial role in the sustainable development of the country as a whole.

A microgrid (MG) is a small, active distribution system that incorporates RES3. MGs consist of components such as wind generation (WG), photovoltaic (PV) power, flexible loads, and an energy storage system (ESS) that serves as a buffer between electric demand and distributed generation. It is described as an aggregation of distributed energy sources, energy storage systems, and loads4. MGs also have the potential to provide electricity to areas affected by natural disruptive events, thereby enhancing the reliability and resilience of the system5.

MGs can operate in either standalone or grid-connected modes. In the event of a fault or other condition that interrupts power from the main grid, the MG disconnects and begins autonomous operation, supplying local loads. Once the fault is cleared, the isolated MG reconnects and resumes grid-connected operation. During autonomous operation, critical loads are prioritized, while other loads are supplied based on the availability of resources5. Critical loads refer to those that must remain uninterrupted under any circumstance.

Severe weather conditions can impact the power system, causing frequency deviations from the standard. While the extent of the impact varies depending on several factors, it is often difficult for the system to recover from such natural disasters. MGs have emerged as a promising source of resilience in such situations6.

Although increasing the penetration of RES into existing systems offers many benefits, it also introduces stability challenges. The intermittent nature of renewable resources (e.g., variations in solar radiation and wind speed) can lead to an imbalance between supply and demand, causing reliability issues, voltage fluctuations, and stability problems in the grid. Additionally, these fluctuations may result in power losses7. However, properly planned and developed MGs tend to have a more positive impact. According to a study in8, MGs can enhance system stability and reduce the levelized cost of energy (LCOE), although challenges remain due to the intermittent nature of RES.

The work presented in11 examines the impact of simultaneously considering battery size, cycle life, and

technology in MGs during both standalone and grid-tied operations. It also highlights how the depth of discharge (DOD) affects the battery"s service life. The authors developed a model that quantifies the equivalent number of complete cycles a battery can undergo over its lifetime, illustrating the difference between a full cycle (complete discharge of a fully charged battery) and a partial cycle. Another study12 explores a different configuration of storage systems, including PV, diesel generators (DG), and a hybrid energy storage system (HESS), which combines batteries and supercapacitors (SCs). This arrangement improves the service life of the battery by incorporating SCs.

For rural areas where expanding the distribution network is either uneconomical or infeasible, renewable energy-based MGs offer a promising solution for providing electricity. Autonomous MGs with RES ensure system security and reliability while offering cost-effective solutions13.

Optimization involves achieving the best possible outcome while meeting specified targets, whether they are maximum or minimum. In the context of MG planning, optimization refers to determining the ideal size, location, and technology of MG components while adhering to various constraints such as investment costs, BESS lifecycle, reliability, greenhouse gas (GHG) emissions, and electricity prices. Researchers employ different optimization techniques based on the specific objectives and constraints of their projects.

In5, the MG components considered include PV, BESS, and loads. The study uses Genetic Algorithm (GA) to optimize the capacity of these components, select a charging strategy, and determine optimal locations while meeting requirements for minimum investment costs, maximum energy supply, and minimal reverse power flow (RPF). The research emphasizes the importance of ESS management and proper MG configuration to meet energy demand and optimize costs in autonomous MGs, which serve as backup power during extended disruptions.

For cost optimization of MGs, factors such as the initial state of charge (SoC), load profile, and operating costs of ESS and RESs are taken into account. By applying optimization techniques, it is possible to achieve efficient use of available resources and minimize operational costs15.

To determine the optimal configuration of hybrid energy sources, eight different MG energy source configurations are evaluated based on the cost of energy (COE) and annual net present cost (NPC), considering seasonally varying commercial and residential loads with different renewable energy fractions. The analysis finds that the PV + BESS configuration is the most economical compared to other simulated feasible combinations. The study also notes that the renewable penetration fraction is inversely related to COE and NPC, meaning that as the fraction of renewable sources decreases, COE increases.

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