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Control Techniques and Strategies for Microgrids

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A B S T R A C T

In recent years the development of f renewable energy increases thereby usage of microgrid increases for sustainability. A microgrid comprises distributed generation, energy storage, loads, and a control system s. They are being used to improve reliability and resilience of electrical grids, to manage the addition of distributed clean energy resources like wind and solar photovoltaic (PV) generation to reduce fossil fuel emissions, and to provide electricity in areas not served by centralized electrical infrastructure in this paper

Keywords: (P/Q) control, voltage and frequency (V/f) control, Control strategies, load management. Islanding capability. Integration of renewable energy.

1. Introduction:

A microgrid is a modern distributed power system using local sustainable power resources .Microgrids that are similar to a conventional grid structure in terms of power generation, distribution, transmission, and control features are assumed as a minor model of actual grid form. However, microgrid technology differs from a conventional grid owing to the distance between power generation and consumption cycles as a microgrid is installed near the load-sites. Moreover, the public interest in environment friendly energy production and rapid growth in demand for power usage increases therefore Microgrids thus emerge as a better solution by operating various distributed energy resources (DERs), The study described the components types of microgrids, advantages and disadvantages of microgrids with respect to storage and generation of energy and control methods that are independently examined in current research.

2. Control methods of microgrid:

A Microgrid is a local grid with control capability, which means it is disconnect from the traditional grid and operates autonomously. Microgrids are cost effective only if powered by local available, renewable energy resource. A micro grid provides backup for the grid in case of emergency.

2.1 P/Q Control:

In microgrid systems, a public control is used, which is called PQ strategy. PQ controls the voltage output of the inverter by injecting the active and reactive powers. This control is used in cases wherein the microgrid is not required or unable to provide voltage or frequency support as a current-controlled voltage source Power Quality (PQ) control in microgrids is a critical aspect of ensuring that the electrical power supplied to connected loads meets specific standards and requirements. Power quality issues can include variations in voltage, frequency, harmonics, and voltage sags or swells. Proper control of these parameters is essential in microgrids to provide a stable and high-quality power supply.

Here's a detailed explanation of PQ control in microgrids:

Synchronization with Central Grid:

In grid-tied microgrids, synchronization with the central grid is essential to ensure that power quality standards are met. Microgrid controllers should ensure seamless synchronization during grid-connected mode.

Power Factor Correction:

Power factor correction is the process of adjusting the ratio of real power (kW) to apparent power (kVA) to improve the efficiency of the power system.

Power factor correction devices like capacitors and synchronous condensers can be employed in microgrids to enhance power factor and reduce reactive power.

Voltage Regulation:

Voltage regulation is a fundamental aspect of PQ control in microgrids. It involves maintaining the voltage levels within acceptable limits.

In microgrids, voltage regulation can be achieved through the control of distributed energy resources (DERs), inverters, and voltage control devices.

Voltage regulators, tap changers, and voltage control strategies like droop control are used to adjust the voltage to meet the desired setpoint

Synchronization with Central Grid:

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2.2 Voltage/Frequency Control :

The microgrid voltage control ensures that the voltage remains within the set point values by adjusting generated or consumed reactive power . A voltage controller is designed with the terminal voltages as input and compared with the reference voltage. The error voltage is filtered using a low pass filter and multiplied by a gain constant to obtain droop control of the voltage source convertor. The output of the voltage regulation control block gives the reactive power that needs to be injected to maintain the terminal voltage according to droop set value

Voltage Control in Microgrid:

Droop Control: Droop control is a commonly used method for voltage regulation in microgrids. It involves adjusting the output of distributed energy resources (DERs), such as generators and inverters, in response to voltage deviations. When the voltage increases above the desired setpoint, the power output is reduced, and when it falls below the setpoint, the power output is increased. This control technique helps maintain voltage stability within the microgrid.

Voltage Regulators: Voltage regulators, such as tap changers, can be used to control the voltage at specific points within the microgrid. These devices adjust the turns ratio of transformers to modify the output voltage.

Voltage Support Devices: Voltage support devices like static synchronous compensators (STATCOMs) or synchronous condensers can be deployed to provide dynamic voltage support. These devices inject or absorb reactive power to regulate voltage levels.

Voltage Monitoring: Microgrid controllers continuously monitor voltage levels at critical points in the microgrid. If voltage deviates from acceptable limits, the controller can issue control commands to DERs and voltage control devices.

2.3 Frequency Control in Microgrid:

Frequency Droop Control: Similar to voltage control, frequency control in microgrids often utilizes droop control. When the frequency deviates from the nominal value, the control system adjusts the power output of DERs accordingly. In grid-tied microgrids, the central grid typically provides frequency support.

Load Shedding and Load Restoration:

In islanded microgrids, if the frequency deviates significantly from the nominal value, load shedding may be employed as a last resort to prevent the system from collapsing. This involves disconnecting non-critical loads to rebalance the system. Load restoration is then performed to reconnect loads when the frequency stabilizes.

Energy Storage Systems (ESS):

ESS, such as batteries or flywheels, can be used to provide fast response to frequency deviations. ESS can inject or absorb power to help maintain the desired frequency. They are particularly valuable in islanded microgrids where the grid does not provide frequency support.

Frequency Synchronization: In grid-connected microgrids, synchronization with the central grid is crucial to ensure that the microgrid's frequency matches that of the grid. This is typically managed by the microgrid controller.

2.4 Current Control Current mode control (CMC) :

Is typically used to track the set point derived from droop or other control approaches. Notably, in this control approach, both loops have finite gain, the inner (current) loop acts as a disturbance that introduces a voltage and phase offset proportional to load current. Therefore, changes in the load impedance will change the system transfer function, thereby changing the amplitude and phase at a given frequency.

3. Control strategies in Micro Grid:

3.1 Islanding Capability:

Microgrids can function independently and cut off from the main grid as needed. Their capacity to island means that they can continue to supply electricity in the event of an emergency or grid outage, increasing the overall reliability of the system.

3. 2 Integration of Renewable Energy:

Microgrids frequently include renewable energy sources such as small-scale hydropower generators, wind turbines, and solar panels. This tactic cuts greenhouse gas emissions and dependence on fossil fuels.

3.3 Energy Storage:

To store surplus energy produced during times of low demand, microgrids commonly utilize energy storage devices, such as batteries. When renewable sources are unavailable or demand is at its highest, this stored energy can be used.

3.4 Load Management:

To improve energy use, microgrids apply advanced load management techniques. This includes demand response, which adjusts power use based on grid circumstances, pricing, or renewable energy supply.

3.5 Distributed Generation:

Microgrids generate electricity locally by using distributed energy resources such as combined heat and power (CHP) systems and microturbines. Decentralization reduces transmission losses while improving energy efficiency.

3.6 Advanced Control Systems:

In order to coordinate and balance the numerous energy sources and loads, microgrids rely on advanced control and management systems. These technologies keep voltage and frequency within safe levels.

3.7 Resilience Planning:

Microgrids are meant to preserve electricity supply amid bad situations such as natural catastrophes or cyberattacks. This entails redundant components and backup power sources.

3.8. Grid Interconnection:

Many microgrids can transition between grid-connected and islanded modes, allowing them to function in collaboration with the central grid when needed and in isolation when necessary.

3.9 Microgrid as a Service (MaS):

Some firms provide microgrid solutions as a service, allowing consumers to reap the advantages of a microgrid without the need for large infrastructure expenditures. This might be particularly enticing to companies and communities.

3.10 Energy Management Systems (EMS):

EMS software may assist optimize energy use, increase load forecasting, and improve overall microgrid operation.

Thistactics used in a microgrid will vary based on its location, purpose, and the energy resources available. Microgrids provide flexibility and adaptability to meet specific energy demands, making them an adaptable option in an ever-changing energy landscape.

4 Tables:

4.1 DIFFERENCE BETWEEN THE CONTROL TECHNIQUES AND STRATEGIES IN MICRO GRID:

S.NO	**Control Techniques**	**Control Strategies**
Definition	The precise methods, algorithms, and procedures utilized to regulate individual components or parameters within a microgrid are referred to as control approaches. These approaches are frequently connected with hardware-level control and are used to accomplish certain control goals.	The overall plans and techniques that govern the functioning of the whole microgrid system are referred to as control strategies in a microgrid. These tactics are often applied at a higher level and need cooperation across numerous components in order to reach larger operational goals.
Purpose	Control approaches strive to guarantee that each component performs effectively and as intended, frequently by altering its behavior in real-time depending on measurements and feedback.	Control techniques seek to enhance the microgrid's overall efficiency, dependability, and resilience. They deal with system functioning, mode transitions, and resource allocation choices.
Level of Abstraction	Control approaches are often implemented at a lower level of abstraction and are more hardware-oriented. They include the precise algorithms, controls, and processes utilized to modify the behavior of individual equipment such as inverters, generators, and energy storage systems.	Control strategies are developed at a higher level of abstraction and are more concerned with overall system behavior and functioning. They entail decision-making procedures, planning, and coordination to achieve macro-level objectives such as maximizing energy consumption, strengthening resilience, or responding to grid disruptions.

4.2 ADVANTAGES AND DISADVANTAGES OF MICRO GRID:

Topic	**Advantages**	**Disadvantages**
Pollution	zero on-site pollution fuel cost Zero emissions	N/A
Renewable source	solar photovoltaic cells small wind turbines mini-hydro	N/A
Response	Fast response	N/A
Charging cycles	High charge-discharge cycles	Limited discharge time
Efficiency	high efficiency	Relatively low end-to-end efficiency
Coupling	Dispatchable	Not dispatchable without storage
Battery storage	Long history of research and development	limited number of charge discharge cycles Waste disposal
Generation	Diesel and spark ignition, Environmental friendly generation resources, Multiple fuel options, Mechanical simplicity	Nitrogen oxide and particulate emissions Greenhouse Gas Emissions, Noise generations

5. Conclusions:

In conclusion. ,Microgrids, as localized power networks, provide a dynamic answer to the rising need for energy. These systems make use of adjacent sustainable resources, which not only increases efficiency but also correlates with the rising interest in ecologically responsible energy generation. Microgrids, unlike standard grids, are intentionally positioned near load areas, allowing for more direct and efficient electricity delivery.The control methods used in microgrids, including as P/Q control, voltage/frequency control, and current mode control, contribute greatly to their autonomy and dependability. P/Q control guarantees that the voltage output satisfies particular requirements, which is essential for maintaining a steady and high-quality power supply. Voltage/frequency control and current mode control improve the microgrid's capacity to regulate deviations and provide a steady power flow.

Microgrids are equipped with a wide range of tools to meet different energy demands and challenges. These include resilience planning, grid interconnection, islanding capability, renewable energy integration, energy storage, load management, distributed generation, advanced control systems Because they are self-sufficient, microgrids are not only more reliable but also a valuable resource in case of crises or grid failures. When energy storage systems are combined with renewable source integration, a continuous power supply is guaranteed, even in times of high demand or when renewable sources are not accessible.

Microgrids are essential for guiding the energy landscape toward sustainability as long as technology keeps developing. Their position is characterized by their flexibility, integration of cutting-edge control systems, and dedication to environmental conscience.

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