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# A Review on Multi-Agent System Control Analysis for Smart Grid System

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**Abstract- This paper reviews the system components, modeling, and control of microgrids for future smart buildings in current literature. Microgrids are increasingly widely studied due to their reliability in the event of grid failure or emergency, their incorporation of renewable energy sources, and the potential they represent for overall cost reduction for the consumer. Greater accuracy in microgrid modeling enables the design of more advanced control methods, resulting in better objective optimization. This paper begins with an overview of microgrids and their components, their importance to both utility providers and building owners, and typical problems that they may be used to solve, as well as modeling challenges that microgrid researchers may face. Lastly, a discussion of current challenges that may be faced by researchers is presented, as well as future directions.**

**Keywords- Multi-Agent System, Solar Panel, MPPT, DG System, AC bus.**

## I. INTRODUCTION

As the world's population and energy needs continue to rise, and a global consciousness of the environment with them, there has been an increase in global renewable energy production. The amount of energy produced around the world from renewable sources (hydro, marine, wind, solar, biomass, and geothermal) increased from 3725 TWh to 5886 TWh from 2008 to 2016, an increase of 58 percent. From 2015 to 2016 alone, the world's total renewable energy generation increased by 369 TWh, an increase of 6.7 percent [1].

In conjunction with increased renewable energy generation (and possibly as a reaction to it), there has been a rise in Microgrid research and development. The US Department of Energy defines a microgrid as "a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid" and which has the capability to "connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode." [2] Microgrids are well suited to a wide range of system sizes and applications, from single residences (sometimes called nanogrids) with a few solar panels and a single battery (see for example to large commercial buildings such as hospitals or even university campuses see for example.

To entire rural villages served by multiple networked microgrids employing multiple renewable energy sources and providing power for hundreds of homes. Microgrids have become increasingly prevalent over the past three decades as energy systems around the world begin to decentralize and shift more toward renewable energy sources.

Since 2001, an increasing number of microgrids, both testbeds and functional, have been implemented worldwide [3]. While much of the research is still done through simulation (due to the relative ease of performing simulations as compared to performing case studies), several of the studies which were analyzed for this review performed real-world case studies. A few studies included building occupancy profiles in their analysis.

Additionally, some studies utilized real-time weather forecasting. The growing need to utilize renewable energy sources (RESs), the declining fossil fuel resources, the necessity to protect the environment and also the importance of pollution reduction caused by the fossil fuel emissions has led to the inevitable fact of using integrated RESs in current microgrids.

From an operational point of view, a hybrid AC/DC microgrid is a gateway, which not only enhances the system performance in the above-mentioned issues, but can also enhance the operational properties of any proposed power system.

Nowadays, the renewable energy market is developing faster than ever; therefore, it is expected that the operational considerations will be taken into account in the microgrids, similar to that of power systems.

Supporting local energy demands as well as coupling AC and DC loads with their corresponding resources to decrease the regular AC-DC-AC conversion losses is one of the outcomes of utilizing both AC and DC microgrids.

Furthermore, increased energy consumption standards in addition to higher reliability and improved power quality and system stability can be achieved by integration of AC and DC microgrids, to form a hybrid AC/DC microgrid.About after a century of domination, many of the reasons that led to the choice of a complete AC power system do not exist anymore.

Increasing amount of DC loads, development of semiconductors and high accessibility of RESs in remote and rural areas have made the utilization of DC microgrids possible [10]. Obviously, the distribution of RESs and the different nations' investments in the implementation of the hybrid AC/DC microgrids are not even. In the global status report of the renewable 2018 As expected, not only do the energy policies of a country have a direct effect on the level and quality of the produced energy and its variation, but the geographical factors also play a substantial role in this regard. The higher the RESs penetration, the lower is the dependency on nonrenewable.

The small interference stability of a microgrid based on power converters is widely reported in references. [4]. However, the stability of major disturbances has not been well studied. In this case, the analysis tool used for conventional small disturbance stability is no longer effective because it is only valid in the operating range of the small disturbance.

In practice, the renewable energy in the microgrid is intermittent in nature, so the operating range will vary within a wide range. Therefore, the small perturbation analysis is not effective in evaluating the stability of large perturbations.

On the other hand, the stability analysis of large disturbances is mainly based on simulation rather than the Lyapunov method. It should be noted that when the operating mode changes, the simulation model must be updated continuously, which is not suitable for high-order and complex systems.

In addition, the stability margin is not available. Although the Lyapunov method is very common in analyzes of transient stability of the electricity system [5], there is very little power

The integration of power converters will result in low inertia of the microgride, which can provide a more challenging response during transients. For distribution level analysis, especially inertimicrogrids, the transient response from a single end-use load will directly affect the frequency and voltage.

**1. Control strategy for Microgrid based on power converter:**

As with the condition in the previous section, the dynamics and stability depend on the control loop. a typical control strategy, including lattice supply, lattice formation and lattice support condition .CC and CV are current and voltage regulators, respectively. i * and v * are equivalent current and voltage sources. P and Q are the measured active power and reactive power, respectively.

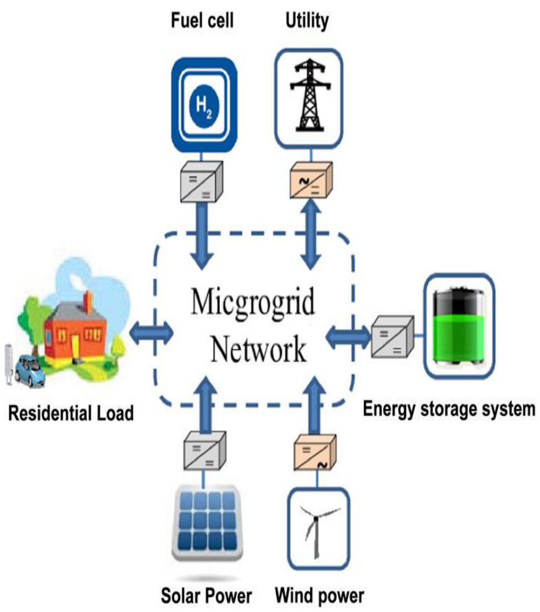


Fig 1. Schematic diagram of power-converter-dominated microgrid.

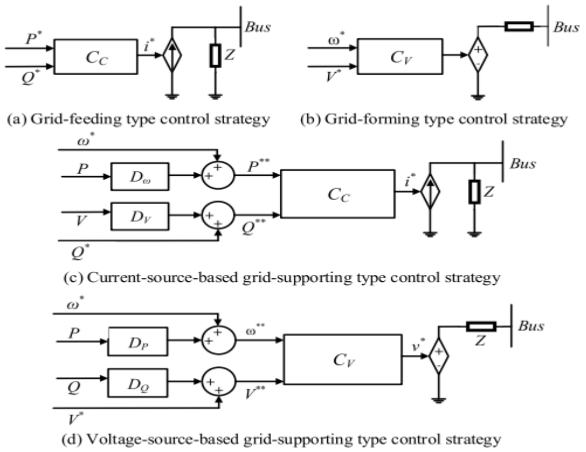


Fig 2. Control strategies for power convert Low inertia.

P * and Q * are references for active power and reactive power. ω and V are the output angular frequency and voltage of the power converter terminal. ω * and V * are references for the corner frequency and the voltage of the terminals on the power converter. Dω and DV are the current management gains for source grid supported and DQ, respectively, are the control gain supported by the mains of the voltage source.

Z is the output impedance of the power converter. That the control goal of the network supply strategy is to inject active and reactive power into the network. The corresponding power converter runs in parallel with other mains-connected current converters in the mains-connected state.

The second method is the lattice formation strategy. Master-slave control is usually used to provide frequency and voltage references.

**2. Great Interference Stability:**

This section discusses the definition and classification of micro grid stability dominated by power converters. Stability of the power system refers to the ability of the power system to maintain stable operation after disturbances [6].

The large disturbance stability in the current converter-based microgride refers to the ability to recover to the previously stable operating state or a new stable operating state after a large disturbance. Electronic devices such as converters are considered .The reference literature summarizes the stability problem with the electronic control system, as shown in Figure 2.

Possible solutions to these stability problems have been proposed, but it is not enough to evaluate the stability of power converters alone. In addition, there are other traditional generators in the system. In the reference [7], the main topics are small disturbance stability and voltage stability, and only the modeling of large disturbance stability is mentioned.

In references [7], inverters and generators are considered from the perspective of high interference stability. According to Figure 2, however, the analysis is based on the inverter level. For multiple converters and system levels, models with reduced order are required.

In summary, the great interference stability in the microgrid based on power converters has not been well studied and further research is needed. The purpose of this paper is to provide a comprehensive and systematic analysis of the large disturbance stability of the microgrid based on current converters.

## II. MICROGRID OVERVIEW AND MOTIVATIONS

At its core, a microgrid is composed of loads, distributed energy resources (DERs), a control system, and a point of common coupling (PCC) with the main energy grid. A microgrid's loads are the components which consume electricity. These may include a building's heating, ventilation, and air conditioning (HVAC) system, lights, industrial loads, residential appliances, plug-in electric vehicles (PEVs), and others. DERs are any microgrid components which produce or store and release energy. These may include solar photovoltaic (PV) panels, wind turbines (WT), combined heat and power (CHP) generators, gas turbines, energy storage systems (ESS), and others.

The control system of a microgrid performs actions such as power flow control, unit commitment and economic dispatch, and communication with the main grid. The PCC is a single point at which the microgrid is connected to the main grid. Microgrids may operate in grid-connected mode or islanded mode. Rural, isolated microgrids which operate exclusively in islanded mode do not have a PCC.

Microgrids are beneficial for many reasons. In addition to improving energy efficiency, like most advanced building control strategies or energy efficiency measures, they help perform the following functions:

- Provide access to renewable energy while reducing harmful greenhouse gas (GHG) emissions
- Support the main electrical grid by reducing congestion and peak loads and providing other ancillary services, including the benefit of more power system infrastructure
- Provide reliable power to isolated, rural areas and also in emergency and natural disaster situations
- Integrate multiple energy resources and energy storage into building systems, resulting in increased control and independence for the end-user
- Decreased risk of failure under decentralized control Microgrids can be employed to solve various different types of problems, on both the grid level and building level.

A few common grid level problems are optimal power flow (determining the optimal levels of power generation to meet forecasted demand), unit commitment (long-term optimal scheduling of power generation units), and economic dispatch (short-term optimal scheduling of power generation units). Common building-level problems that may be solved with the help of microgrids include load forecasting (short-term prediction of power demand), energy cost optimization (determining when to draw power from the grid and how much to draw in order to minimize energy costs and/or maximize profits), building energy management (scheduling appliance use, including HVAC, to use energy with maximum efficiency), and demand response (reducing energy use during peak times in response to grid signals).[7][8]

### 1. Multi Agent Systems Approach:

- Multi Agent Systems Autonomous components and coordination are the basic ingredients of any distributed system. Distributed systems that involve many heterogeneous entities have some major limitations.
- Interactions among participating entities are fixed by application developer while coding and hence they lack run-time adaptive behavior

### 2. Recent Applications of Multi-Agent Systems:

In Microgrids the use of MAS is an up-and-coming technology in power engineering applications. It has been developed for a wide range of applications such as diagnostics, condition monitoring, power system restoration, market simulation, network control, and automation in power systems [9].

An intelligent agent is presented by the incorporation of features such as;

- **Autonomy:** The ability to operate without any direct human or other intervention, with a certain control over its actions and decisions
- **Reactivity:** The ability to perceive changes in the environment and react in a timely fashion,
- **Pro-activeness:** Without being limited to reacting to input, an agent must be able to take initiative to exhibit goal-oriented behavior, and

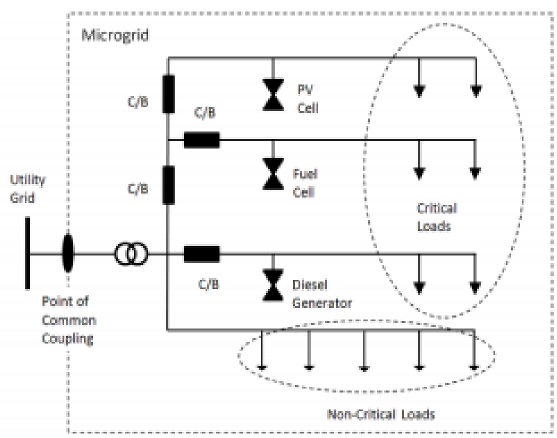


Fig 3. An example microgrid implementation

### 3. Microgrid Classification:

Depending upon the output voltagenatureused for the sensitive load, microgrids are classified as follows: AC microgrid-AC microgrid. A, B, C are radial feeders and loads are connected, which Combined together to form the distribution system.

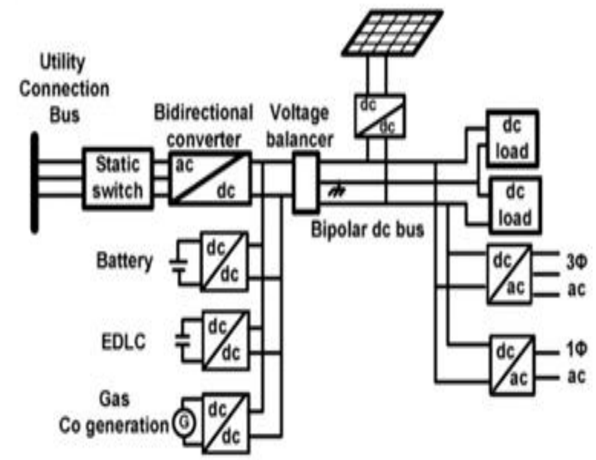


Fig 4. Schematic diagram of low voltage dc Microgrid [16]

**4. The feeders:**
A & Bare connected to the micro sources where the sensitive loads are connected. The loads which arenon- sensitive are not affected by the power quality issues on the grid that is feeder C.

**5. DC Microgrid:**
Some appliances which needs dc power it can be from the battery or by using rectifier to convert ac to dc like mobile phones, TV, electric vehicle , laptops, etc use dc power either from rectification of the ac source or from the battery. Each appliance has an adapter in which rectifier is embedded which rectify ac to dc to run them or to charge the battery.

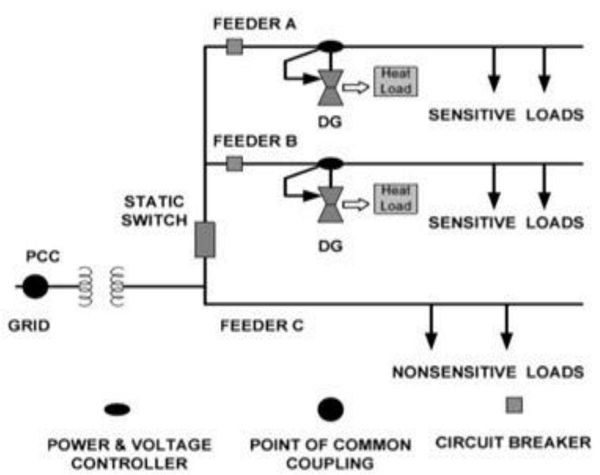


Fig 5. Simple schematic of an ac Microgrid. [16]

The benefits of dc microgrid can be stated as follows: Use of inverters in ac microgrid between dc load and dc appliances makes the efficiency of dc microgrid higher.[16] In dc microgrid we don't need to synchronize utility grid and dc grid and also reactive power compensation is not needed.

DC microgrid has some disadvantages as follows: Private dc distribution lines are needed to be laid to use dc microgrid. Since in dc supply magnitude remain positive zero crossing is not present therefore protection becomes difficult. Only loads which are dc can be supplied without any conversion of supply.

**6. Control Strategy of Micro Grid:**
In traditional power system several problems like voltage and frequency variation, stability factor, switch gear failure is faced. as traditional power system is large so variation in this case is not sever, but in micro grid steady and transient characteristics is different because of imbalance load and the electricity is coming from uncontrollable source like solar cell, wind mills etc. A control system must be design to make system reliable and safe. Generally three kind of control strategy is used to make system more reliable these are real and reactive power flow control, since voltage and frequency fluctuate more in small system so voltage and frequency control also needed and last droop control.

**7. Centralized Approach:**
Centralized approach handles whole system with the help of complex central processing element, communication which is rather important unit and from faraway control distribution system issued, where communication system is consists of a sensor which sends data to other units. It is a main central unit, which is collected by decoder and for each control equipment different signal is generated and send them to controller.[5]Centralized approach is able to adopt the constant power output mode.

A schematic is shown for centrally controlled micro grid. In LV stations controller is installed. Stability control cost managing function and other different functionalities are included in this approach. The next controller is LC (load controller) located at Micro source controller MC. Process of interruption of load like load shedding controls load. Active and reactive power generated by the MSis controlled by MC Controller [16]

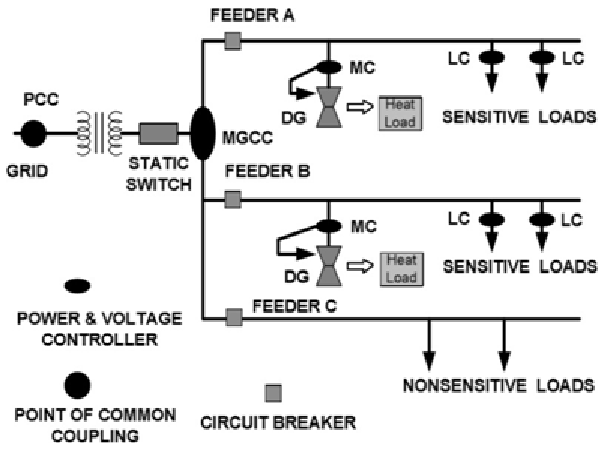

Fig 6. Simple diagram of centrally controlled Micro grid.[16]

## III. LITERATURE SURVEY

**T. Logenthiran, et.al. (2015)** this paper presents an intelligent control of a Microgrid in both grid-connected and islanded modes using the multi-agent system (MAS) technique. This intelligent control consists of three levels. The first level is based on local droop control, the second level compensates power balance between the supply and the demand optimally, and third level is at the system level based on electricity market. An intelligent multi-agent system was developed and implemented based on foundation for intelligent physical agents (FIPA) standards by representing each major autonomous component in the Microgrid as an intelligent software agent. The agents interact with each other for making their own decisions locally and optimally.[1]

Shanna Luo et.al (2017) According to controllability theory of nonlinear coordinated control with multi-agent, this paper proposes a coordinative optimization method based on the model predictive control (MPC) to achieve the coordination control of energy allocation.

Between the micro sources with the incremental cost of consistency algorithm for leader-follower, using an interactive algorithm to achieve the exact optimal solution to the optimization problem based on MPC, each micro source as an intelligent agent through the interaction between the adjacent micro sources, while achieving coordinated optimization control in microgrid to meet the incremental cost.

The obtained results show that multi-agent systems (MAS) using MPC for coordinative optimization control of microgrid can effectively manage the micro source, to fully explore the key role of individual intelligence in group cooperative behavior. The effectiveness of distributed consistency algorithm & MPC algorithm are verified by examples. [2]

**Leo Raju et.al (2017)** This paper aims to establish an Arduino based Multi Agent System (MAS) for progressive demand side response of a solar micro-grid. High penetration of renewable energy resources needs new coordination and control approaches to meet the stochastic nature of the environment and dynamic loadings.

Here, a Multi Agent System is used for an improvised and strengthened, distributed, self-governing energy management of the micro-grid to dynamically and flexibly adapt to the changes in the environment. Our micro-grid contains two solar Photo Voltaic (PV) systems, local consumer, and a battery. A simulation model is developed in Java Agent Development Environment (JADE) for dynamic and effective energy administration, which takes an informed decision and chooses the most feasible action for every one hour interval to stabilize, sustain and enhance the solar micro-grid. Moreover, environment variables are sensed through Arduino micro controller and given to agents of MAS. The resulting actions are reflected in the LED out puts which can be readily deployed in the actual field. [3]

**Leo Raju et.al (2017)** the aim of this paper is to develop a Multi Agent System (MAS) for robustness Management in electrical energy management of a micro-grid. We take into consideration a grid associated micro-grid which contains two systems each contains solar Photo Voltaic (PV) system, wind system, a local consumer, and a battery. Foremost we compute the load trends and solar and wind power produced in the two solar units.

Following which we go on to implement grid robustness management using Multi Agent System based distributed energy management of micro-grid with smart grid structure. We develop a simulation model in Java Agent Development Environment (JADE) for dynamic model which takes into account the closely knit nature of solar power, impermanence of load, dynamic appraising of grid and variation of critical loads and choose the best possible action every hour to stabilize and optimize the micro-grid Dispute of certain failures.

Furthermore, MAS increases the functional efficiency and thereby maximize the power production of solar micro-grid and curtails the operational cost to minimum. Thus MAS in micro-grid leads to optimization of both capital and environmental resources. Simulated working of solar generators and loads are analyzed by conducting simulations for the various agent motives. Simulation studies show the balancing of micro- grid during the grid robustness. [4]

**H.V.V. Priyadarshana et. al (2019)** this paper presents an implementation of a Multi-Agent based Energy Management System for a micro grid with JADE (Java Agent Development Framework). The MAS is applied for a micro grid consisting of different distributed energy sources such as solar PV system, wind power system, diesel generator system, storage system, and critical and noncritical loads. Different agents are developed on JADE framework and they are given responsibilities of relevant DES's (Distributed Energy Source) and loads.

A runtime environment for Agents is created and a dynamic simulation model developed through JADE considering the intermittent qualities of renewable energy sources. The case studies presented on this paper are modeled on JADE platform. Developing MAS in JADE runtime environment using AOP (Agent-Oriented Programming) helps agents to operate with all their autonomous, rational, reactive, and proactive qualities.

The use of MAS concept in micro grids improves its efficiency in various aspects. The MAS based micro grid management system implemented in JADE platform and can be used to carry out various simulations to study about agent behaviors in different environments and different system objectives. The main purpose of the paper is to prove the possibility of using multi-agent concept in micro grid energy management systems.[5]

Summary of previous reviews Within the past decade, as microgrids gain popularity and become better researched and understood, there have been a number of surveys investigating the state of the art as well as identifying challenges and future research directions and investigate energy management systems in microgrids–their functionalities, architecture, control philosophies, and existing software.

Explores the modeling, planning, and energy management of microgrids with cooling, heating, and power cogeneration capabilities Reviews various distributed control and management strategies for microgrids and lists future trends in distributed control.

Identifies common barriers and success factors to real-world microgrid implementation provides a comprehensive review of microgrid control principles, categorizes major control strategies, and identifies trends in the literature [9–8] review multi-agent systems (MAS) and their applications in microgrid control [12] presents the main issues related to the design and control of nearly/net zero energy buildings (nZEBs) [3] and [4] survey the optimization objectives, tools, techniques, and algorithms that are applied to the challenge of microgrid control [16] explores the latest analytical and approximation techniques used to model uncertainties in renewable power generation in microgrids [7] investigates Microgrid technologies, drivers, applications, and challenges.

Most recently, [5] reviews microgrid energy management systems, focusing on their decision making strategies, uncertainty quantification methods, and communication technologies.

## IV. CONCLUSIONS

Multi Agent Systems, in the past few decades, have attracted immense attention in the scientific research community. However, the complexity of design and other several factors are the stumbling blocks for the technology. Also, there have always been questions regarding the choice of application area and suitability of MAS.

This work attempted to present a survey of the various areas, in control engineering, where multi agent systems have been successfully and efficiently implemented. Several future research directions are evident when it comes to building-integrated microgrids. These are the incorporation of advanced occupancy models, further development of agent-based modeling, and building-to-grid integration.

Advanced occupancy models are already in use in building control literature. As they are integrated into microgrid models, researchers will be better equipped to optimize energy usage, economic gain, and thermal comfort simultaneously. In addition, by using new sensing paradigms like Sensing by Proxy, researchers may gain the ability to incorporate real-time occupancy states into energy management controllers.

As microgrid models become more and more complex, the need for flexible and reliable optimization strategies will become more pronounced. Agent-based modeling may be capable of easily incorporating the needs of the grid, the buildings, the occupants, and the market into a single control structure, as well as making it a simple matter to add more agents as they are added to the microgrid.

Finally, continuing to integrated buildings, micro grids, and the power distribution grid will provide a way for the increasing power demands of society to be met without overtaxing existing infrastructure and without a drastic increase in costs, benefiting energy suppliers and consumers alike

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