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Microgrid: Innovation, Challenges and Prospects

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Abstract: In the present world where environmental issues are posing a great threat to the survival of mankind a better yet effective way of reducing carbon emissions and improving the environment by less usage of fossil fuels was suggested. This approach was called microgrid (MG). Renewable energy resources could be used effectively to produce electricity and can be easily integrated with the conventional grid. This paper elaborates on the basic concept of microgrid, and then describes the challenges and future prospects of the microgrid. Distribution generators along with energy storage devices and proper interfacing power electronic devices are used. Working on the basis of the type of microgrid is also discussed in this paper.
Keywords: Renewable energy resources, distributed energy, AC microgrid, DC microgrid, energy management.

I. INTRODUCTION

Electrical frameworks are starting to change because the rapid urbanization of the world's population is creating great social, environmental and structural strains on the city's people. During the last decades, the research, development and implementation of renewable energy resources have been strongly impelled mainly as distributed generation due to variability and intermittence of RES (renewable energy resources). Fossil fuels are non-renewable resources and will be used up by mankind one day. So a method should be developed to enhance use renewable new clean energy, and convert these clean energy into electrical energy, which can not only increase the diversity of energy use, but is also an inevitable choice to solve the problems of increasing depletion of fossil energy, environmental pollution, increasing cost of generation and transmission losses and increasing reliability.

Researchers in the 1990 have proposed a concept that argues dependability and strength notwithstanding catastrophic events and falling forward breakouts. They built up arrangements where the subsections of the system that could be disconnected from the centralized system were made. This approach has been called the microgrid.

II. MICROGRID CONCEPT

A small self-sufficient local electrical framework that supplies energy independent of the centralized energy system serving a discrete geographic footprint is called a microgrid. MG transfers power at lower voltages and lower generation so there is no need for stepping up of power. In a MG system, backup resources are unnecessary because a single user does not have to supply a general load during critical consumption periods. The microgrid could tackle the present energy crisis as the transmission losses are reduced. Additionally, a microgrid provides significant reduction in generation costs while providing reliable and sustainable energy to loads. The cyber security issue is addressed as well due to the localized nature of the system. Microgrid technology is suitable for regions with an underdeveloped transmission infrastructure, such as remote villages. It also serves a range of customers from residential buildings to commercial entities and industrial parks with the conditions that some loads or all of them are controllable.

A Microgrid is defined as a group of Distributed Energy Resources (DERs), including Renewable Energy Sources (RES) and Energy Storage Systems (ESS), plus loads that operate locally as a single controllable entity.

Two different types of generation technologies are applicable for microgrid design such as renewable distribution generation (solar thermal, photovoltaic wind, fuel cell, CHP, hydro, biomass, biogas, etc.), and non-renewable distribution generation (diesel engine, stream turbine, gas engine, induction and synchronous generators, etc.)[1].

Storing of energy is vital in order to authorize renewable energy resources as a reliable contributor to the centralized grid and to provide a successful operation of microgrids. The energy storage process plays an important role in maintaining the required demand-supply balance. Microgrid system has different kinds of load and it plays a vital role for its operation, stability and control. An electrical load can be categorized as a static or motor/electronic load. The microgrid can supply various kinds of loads (such as household or industrial) which are assumed to be sensitive or critical, and demand high-level reliability. This kind of operation requires several considerations such as priority to critical loads, power quality improvement supplied to specific loads, and enhancement of reliability for pre-specified load categories [1, 3]. Distributed generation (DGs) technologies require specific converters and power electronic interfaces that are used to convert the generated energy to suitable power types directly supplied to a grid or to consumers [2].

III.MICROGRID TYPES

Based on operation modes microgrids are classified as grid-connected or isolated/islanded connection mode allowing the microgrid to increase the reliability of electrical supply. Based on the type of distribution system, microgrids are classified as AC, DC or hybrid power systems. A DC power system can be used for both connection modes. The distribution network of DC can be one of three types: monopolar, bipolar or homopolar. The first two arrangements are normally used for HVDC long distance transmission systems while the last is mainly used in low voltage distribution systems (LVDC network).

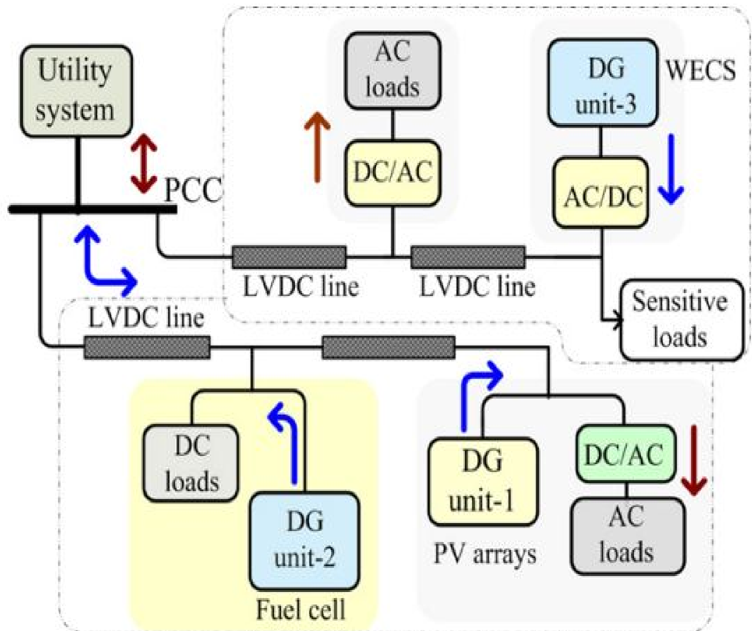

Fig 1. DC microgrid

A typical AC microgrid system interconnected with the MV system at the PCC is shown in Fig. 4. The main grid could be an AC or DC bulk system. The DG units and ESS are connected at some points within the distribution networks. Part of this network that has DG units and load circuits can form a small isolated AC electric power system i.e. an AC microgrid [4]

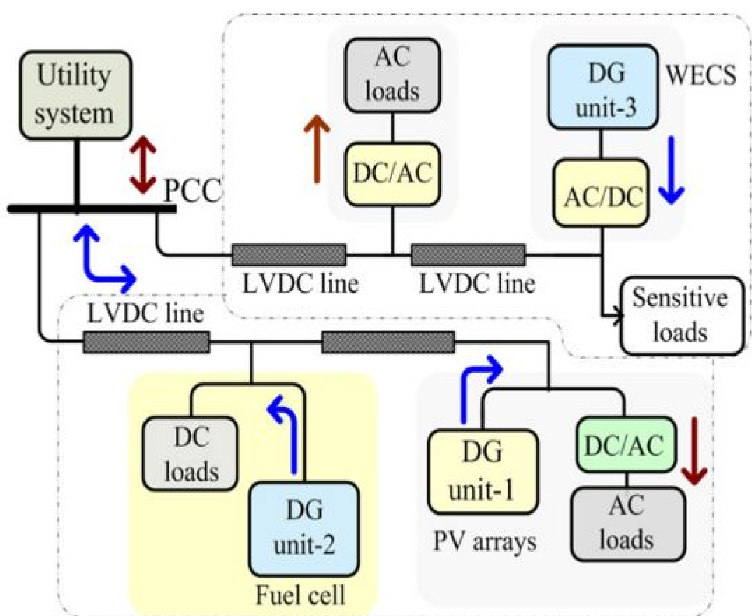

Fig 2. AC microgrid

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The structure of a hybrid microgrid is schemed in Fig 3, where, it is connected to the main grid through a static transfer switch (STS). [5,6] Power flow between the networks and the utility grid is controlled through converters.

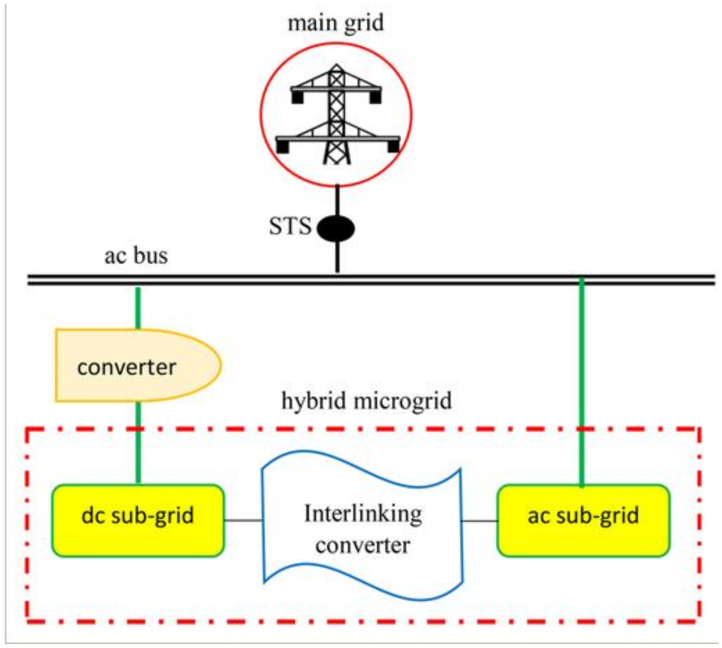

Fig 3. Hybrid microgrid

IV. MICROGRID OPERATION AND ARCHITECTURE

MG operates in grid connected and islanded mode. During the grid-connected mode, there is bidirectional flow of power. When the centralized grid fails, the microgrid can be separated from the grid and changed to the islanded mode of operation by protection action and islanding control, and supply power for critical loads. After the elimination of grid failure, microgrids can be connected with the distribution grid by grid-connected control and switch to grid-connected mode of operation again. Grid-connected microgrids have a Point of Interconnection (POI) or Point of Common Coupling (PCC) with a large power network and are capable of seamless transition to islanded mode. [8] During island/isolated mode power is supplied mostly to critical loads connected to the system.

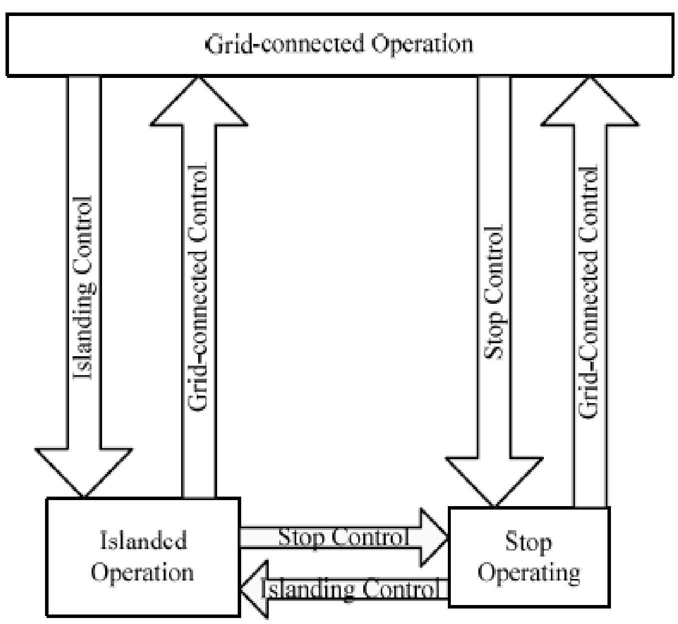

Fig 4. Microgrid operation

The basic microgrid architecture comprises distribution energy resources (DER), energy storage systems (ESS), and flexible load and control system and power electronic interfacing devices. A microgrid typically contains a communication infrastructure between the Microgrid Central Controller (MGCC), switches, components' primary control, and metering devices. Depending on the upper grid requirements and topology, there may also exist a communication pipeline between the MGCC and a tertiary control layer. [8]

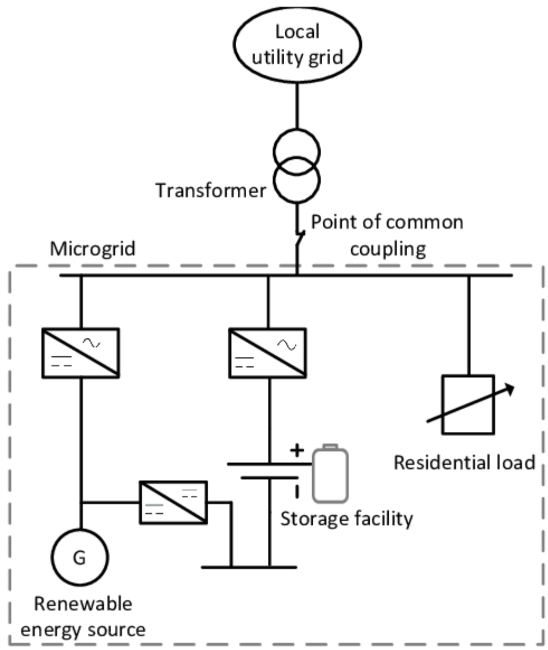

Fig 5. Microgrid architecture

V. MICROGRID CHARACTERISTICS

Compared to the bulk power system, MG are comparatively smaller in size and capacity thereby having higher uncertainty due to reduced number of loads. They have a higher penetration of RES. Furthermore the microgrid feeders are relatively short and operated at medium voltage levels hence they have a lower reactance to resistance ratio (R/X) in comparison to the bulk systems. Electric power in microgrids is supplied by distributed energy resources and relatively small synchronous machines due to which system inertia becomes considerably low in microgrids as compared to bulk power systems. Also main concern in island microgrids, especially in remote communities with small distribution systems, is their relatively low short circuit capacity. In such systems even a small change in the microgrid configuration for example starting or shutting down of a diesel genset can result in relatively large voltage and frequency deviations leading to inverter shutdown. [7]

VI. CHALLENGES

MG operation faces challenges in many aspects and some of them include;

1) *Economic Operation And Energy Management:* MG achieves optimal operation and reasonable distribution of energy by controlling and regulating values of active power output of DG, interfacing the bus voltage of VSI and interfacing the current of CSI etc. The operational economy of the microgrid is directly related to the interests of the users and the main power grid. During the grid connected option there is power exchange between MG and distribution power network. At time of isolated operation, not all the load in the microgrid will be supplying power by internal distributor generators but only the critical load will be served. Thus providing proper economic operation while maintaining energy balance between supply and demand.
2) *Simulation and Analysis of Microgrid*: In microgrids, there are both synchronous generators and other rotating equipment with a large time constant and fast response power electronic devices. In the event of system disturbances, there are electromagnetic transient processes that change fast in microseconds, electromechanical transient processes that change in milliseconds and slow dynamic processes that change in seconds.

3) *Power Quality Analysis:* Electrical power quality is the ability of a power system to function satisfactorily in its electromagnetic environment. It is the measure, analysis and improvement of bus voltage to maintain a sinusoidal waveform at rated voltage and frequency. [8] Power quality issues in microgrids are mainly because of integration of various renewable energy resources with the grid. Other reasons include transition of microgrid from grid connected mode to isolated/ islanded mode. Incorporation of various power electronic devices induces harmonics in the system because of their non-linearity. A load attached to the microgrid having considerable reactive power demand also deteriorates the power quality of the whole system. In order to improve the power quality of the system energy storage devices, filtering equipment or proper control schemes are used. A two-level and a three-level controlled voltage structure were developed as the active power conditioners (APC) to improve the power quality [10]. Digital power processor in a closed loop scheme was proposed to remove and compensate for the unwanted harmonic content of the power system [11]. A combined system of active power filter and static VAR compensator is used to reduce the harmonic and thus improve power quality of microgrids [12]. Also an optimal power control strategy is presented for a microgrid operating in island mode. The proposed control strategy is based on the particle swarm real-time self-tuning method [13]. PWM were also used to improve the generator's power factor and produce fewer harmonics [14].
4) *Protection of MG and Distribution Generators*: Accurate determination of fault is difficult because of the various distributed power and energy storage devices used. As MG switches between two modes of operation hence necessary adjustment should be made to the traditional control which makes the process more complex. Various protection schemes like distance and differential protection, total harmonic distortion based protection and voltage based protection are found to be suitable for protection of MG with DG. Communication is also an important aspect of control in microgrids and IED’s i.e. intelligent electronic devices are incorporated in the grid for this.
5) *Power Supply and Balance Stability*: It pertains to the ability of the system to maintain power balance, and effectively share the demand power among distributed energy resources, so that the system satisfies operational requirements. These types of stability issues can be categorized as voltage and frequency stability. Voltage instability occurs because of inadequate reactive power supplied, dc link capacitor or because of distributed energy resources power limits. The main cause of frequency stability is inadequate active power supply or poor active power sharing. Because of voltage instability the system has large power swings, low steady state voltages and high dc link voltage ripples.
6) *Control System Stability*: These issues in microgrids may rise due to inadequate control schemes and/or poor tuning of one or more pieces of equipment controllers. This category of stability is subcategorized into Electric Machine and Converter Stability. Electric machine stability in microgrids is dominantly associated with poor tuning of synchronous machines’ exciters and governors whereas converter stability refers to tripping of DER’s, instability introduced by inverters, inner voltage and current loops etc.

VII. FUTURE

As MGs grow in number and complexity, they will require sophisticated digital automation and smart management in order to become reliable alternatives to the traditional grid. Advancements in technology such as the Internet of Things (IoT) enable automated energy management which manages multiple components and changing conditions. Based on available parameters, the system can make decisions that optimize price, reliability, and the use of clean energy.

Islanded MG are standalone systems that help in bringing electricity to rural areas, regions that lack basic infrastructure and places whose infrastructure was catastrophically damaged. As renewables become even more cost-effective to deploy, further expansion of microgrids by using it not only for critical loads but vast areas can be done.

VIII. CONCLUSION

Use of renewable energy to provide electricity to a vast area could not only prove to be environmentally good but can also reduce burdens on the centralized system and be economically fruitful to the world as whole. By using localized grid for providing energy a lot of investments like infrastructure erecting cost, transmission losses, maintenance and labour cost could be greatly reduced. With the advent of new technology like the IoT, controlling and providing reliable quality power through microgrids would not be a problem. Also during blackouts or complete grid failure or during emergency situations microgrid turns out to be a good alternative as it can work both in grid-connected and isolated/islanded mode. And the areas where erecting of transmission lines poses a problem, microgrids can be a source of providing electricity to the village/ remote area.

The general challenge still remains of how to run the microgrid and its components optimally.

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