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A Study on Hybrid DC Micro-Grid System

Ritu Gupta
PG Scholar
Department of Electrical Engineering, LNCT, Bhopal

Amit Shrivastava
Associate Professor
Department of Electrical Engineering, LNCT, Bhopal

ABSTRACT: With the growing demand of electricity, deployment of microgrid is becoming an attractive option to meet the energy demands. At present, large-scale wind/solar hybrid system is of great potential for development. The large-scale wind/solar hybrid system is of higher reliability compared with wind power generation alone and solar power generation alone However, a grid connected microgrid suffers a crucial stability issues during a fault in utility grid. For stable operation of microgrid during fault in grid. In this paper transient stability of the microgrid is studied during fault in utility grid. This research work presents the design and implementation of a hybrid renewable energy system that allows a cost-efficient and sustainable energy supply of the loads. The integration of the solar system with the network is rather complex and expensive. With this construction proposal, however, it is not only possible to create an economical and simple hybrid system, but also a reliable, efficient and economical system.

KEYWORDS: Renewable Energy system, PV Array, Wind System, Fuel Cell, DC/DC Converter, Controlled Inverter, Grid System

I. INTRODUCTION

Energy incorporates a very important role for the development of a nation and it's to be preserved in a very most effective manner. Energy is that the ultimate issue accountable for each industrial and agricultural development. The new technologies that are developed to provide energy within the most environmental friendly manner and conservation of energy resources in most economical means has equal importance. The utilization of renewable energy technology to satisfy the energy demands has been steady increasing for the past few years. Import of petroleum products constitutes a serious drain on our foreign exchange reserve. Renewable energy sources are considered to be the higher choice to meet these challenges. The necessary drawbacks related to renewable energy systems are their inability to ensure reliability and their intermittent nature. A serious challenge of grid integration an increasing number of renewable-energy-based distributed generators is featured whereas making certain stability, voltage regulation, and power quality [1].

Microgrids are local energy networks that involve renewable energy sources and storage systems. They have the capability to be locally controlled. Therefore, they can disconnect from the grid when there is a blackout, or a fault at the main grid, and continue to supply a portion of their local loads in a so called “islanded mode.” Several states in the USA invested millions to promote high penetration of microgrids as a part of their climate resiliency plans against natural disasters, especially after hurricane Sandy. Since microgrids typically include renewable sources and batteries, DC microgrids [2] will have the capability to increase the overall system efficiency.

The microgrid consists of different DG, ESSs and loads, and the aim is to integrate an ac/dc converter so that the microgrid can operate both in islanded mode or grid connected. As it can be seen on the figure, different types of energy generation systems are included in the microgrid [3,4]. On the one hand, various solar panel arrays and a mini wind-power system are installed on the roof, connected to the microgrid through dc-dc and an ac-dc converter, respectively. On the other hand, two programmable dc sources have been included with the aim of programming different generation profiles and emulating the behavior of other DG units. Regarding the loads connected to the system, in this case different programmable loads are employed [5]. This enables the emulation of different load profiles to test diverse operation conditions in the microgrid. In order to compensate energy generation and demand differences, different ESS units are used on the microgrid.

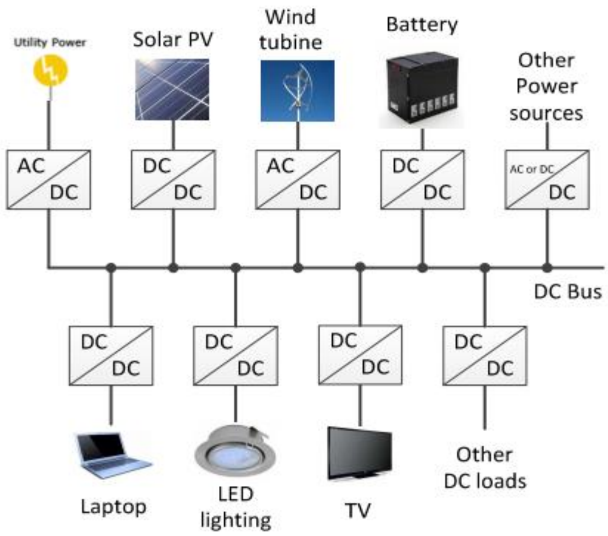

Figure 1: A typical DC Microgrid

Micro-grids are small scale power systems that use distributed renewable and/or non-renewable generations and energy storage systems to supply power to local loads. Most of renewable sources and energy storage devices, such as Photovoltaics (PV), fuel cells and batteries, generate DC power, and more and more electrical loads in residential houses or commercial buildings use DC power, such as laptops, LED lighting, etc. In a DC micro-grid, these sources and loads are connected directly via a common DC bus [6].

Fig. 1 shows the structure of a typical DC micro-grid. Compared with the AC systems, DC micro-grids have the advantage of higher efficiency by eliminating the wasteful AC to DC and DC to AC conversion stages [1]. DC micro-grids hold extraordinary promise for a wide variety of situations [6], but there are still a few barriers to deploy this technology, such as the initial cost of the system, lack of standards and code of practice, etc.

To improve the system performance, the DC micro-grids must be controlled in an optimal way based on system control law. Many control methods have been proposed, and they are classified into three categories [3]:

Independent control: each power converter in the DC micro-grid operates independently. The system is low cost and reliable, but the system performance cannot be optimized because each power converter does not know the operation of other power converters in the system.

Centralized control [4]: all the power converters in the DC micro-grid are controlled by a central controller through external communication links. Various control methods, such as active load sharing control, can be easily applied to the DC micro-grid, and the system performance can be optimized. However, the reliability of the system is degraded due to the whole system depends on the central controller and external communication links.

Distributed control [3][5][6]: the DC micro-grid control is distributed to each power converter controller. The system can still function under the conditions of single or multiple power converters failure, so it has better reliability than the system under centralized control. For some distributed control methods, low bandwidth external communication link for each power converters are still needed for correct operation [5].

II. DISTRIBUTED GENERATION

The first power systems were DG systems designed to meet the needs of local areas. The development of technology and the increase in energy demand have led to the development of large centralized networks linking regions and entire countries. Full load DG applications showed greater benefits in terms of power and performance as well as reducing transmission losses.

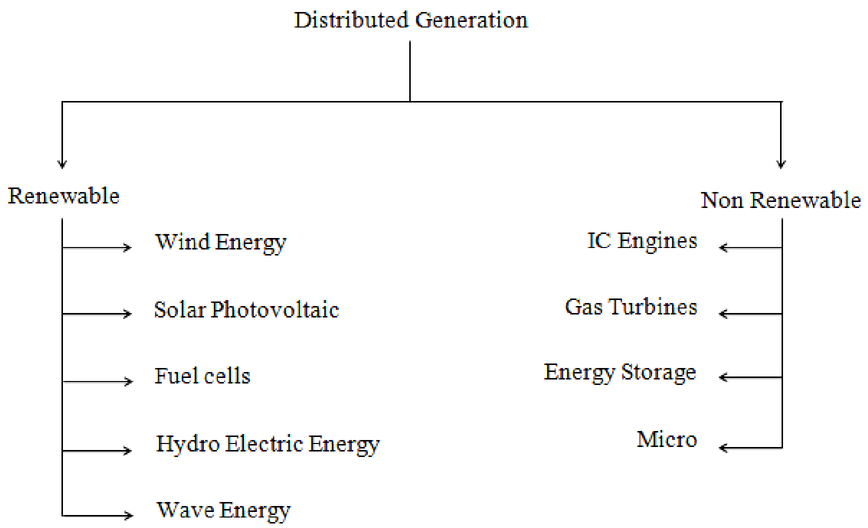

Figure 2: Distributed generation

A. Modelling of PV Array

The photovoltaic system connected to the grid is a more reliable solution to increase the demand for energy. The network connection of a photovoltaic power generation system has the advantage of more efficient use of the generated energy [2]. The PV systems are connected to the grid via the inverter, which converts the DC energy generated by the PV modules into alternating current. The inverter technology is very important to ensure a reliable connection and safe operation of the photovoltaic network.

Again, the power generated by a single module is not sufficient to meet performance requirements for most practical purposes. PV Molds These inverters can be used to convert the DC output into AC and use it for motors, lighting and other loads [8]. The modules are connected in series for more voltage and then in parallel to meet the current specifications. A PV module consists of variety of series cells NS whereas the cells are connected in series and parallel in PV arrays wherever the arrangement defines the maximum output voltage VM and maximum output current IM [4].

The cells are made in mono crystalline or polycrystalline structure relying to the purity of semiconductor [5–7]. The polycrystalline cells that give limited potency around 13–14% are less economical comparing to the mono crystalline that the efficiency will increase up to 20. This circuit shown in Fig 5 includes a photocurrent source, a diode, and serial and shunt resistors that are referred to as one-diode or five-parameter model [8]. The calculations of the one-diode model are depended to the output current:

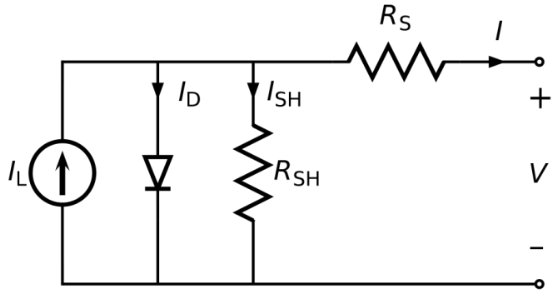

Figure 3: Electrical Equivalent of PV Cell

$$I_o = I_{PV} - I_D(V) - I_{SH}(V)$$

Where (V) shows the dependency of diode current and resistor current to the terminal voltage whereas they're independent from irradiation value.

B. Wind Energy

The kinetic energy of the wind causes the wind turbine blades to rotate. This leads to a rotation of the generator shaft, which is connected to the rotor blades. The generator converts the mechanical energy of the rotating shaft into electrical energy [16-18]. It is optional to connect the slow shaft of the rotor blades with a reducer to the high speed shaft of the generator. In some cases, transmissions are not desirable because they are expensive, cumbersome and heavy. A multipolar generator is an alternative possibility of a gearless system.

The power cable transfers electricity to a transformer. The transformer increases the low voltages of the generator to the level of distribution or sub-transmission of the connected system

The wind turbine (WT) converts wind energy to mechanical energy. The power output of a wind turbine can be expressed as shown in Figure 3.2 and the aerodynamic torque is given by:

$$P_w = 0.5 C_p \rho A V_w^3$$

$$T_w = \frac{P_w}{\omega_W}$$

Where P_W = Wind Turbine Power (in Watt)

P= Air Density (in Kg/m^3)

A= Rotor Area (in m^2)

V_W = Velocity of wind (in m/sec)

ω = Turbine rotor speed (in rad/sec)/

C_P = Power Co-efficient, It is the function of tip speed and blade pitch angle.

C. Fuel Cell Systems

Fuel cells offer clean, non-toxic energy at relatively good energy densities (higher than lead-acid battery) and high reliability. Fuel cells cannot store energy as opposed to a battery; however, they can continually produce electricity. Presently the fuel cells being popularly used are:

Solid oxide

Molten carbonate

Proton exchange membrane

Phosphoric acid

Aqueous alkaline

The efficiency of fuel cell systems are ~ 50 %. Along with heat recovery systems the efficiency can be as high as ~ 80 % [2]. Description of the electrochemical process involved in the power generation process of a fuel cell is beyond the scope of this paper. This section briefly describes the electrical characteristics of fuel cells and their implications on the power electronic interface circuitry.

III. Transient Stability in Micro-Grid

A microgrid is represented as a combination of different distributed energy resources and various loads. Stability issues arising in microgrid are very similar to those arising in large power system viz transient stability, voltage stability and small signal stability [2]. The common reasons of these stability issues are given in Fig. 4.

In this paper the main focus is on transient stability of microgrid. Transient stability of a microgrid can be defined as its ability to retrieve its stable operation after a large disturbance. Micro sources have a very little spinning reserve and reactive supports so it is important to perform a detailed transient stability analysis of a microgrid. Fault produces a transient stability problem in microgrid and it is essential to disconnect the faulty part from the healthy part. If the fault is in utility grid, the whole microgrid system undergoes voltage and frequency collapse [8].To prevent microgrid collapse due to a fault in utility grid it is necessary to isolate the microgrid.

If there is a loss of generation or any generator is not in service like WTG due to unavailability of wind, then again load shedding is required unless any storage or battery is available to feed all the loads. A sudden trip of load may also lead to transient instability. Storage devices can give a better solution to this problem.

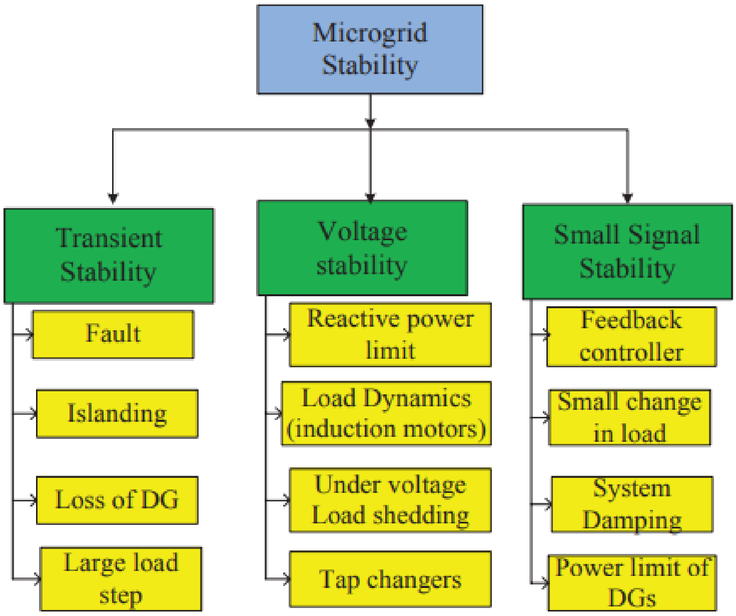

Figure 4: Categorization of microgrid stability

IV. POWER BUFFERS

Low generational inertia and lack of damping elements cause stability concerns in dc microgrids. Power buffers have been introduced to damp volatile load demands and improve microgrid's stability. Power buffer is a power electronics converter with large storage components (e.g., capacitors), which can decouple dynamics of a power distribution network and electronic loads by adjusting its input impedance and stored energy. Typically, power buffers are controlled individually to serve local loads. Alternatively, collective operation of power buffers is considered here to extend their damping effect to neighbouring loads. Additionally, the group operation allows buffer designs with smaller storage components. A supervisory control to manage energy-impedance profiles of power buffers across a grid would require a complex communication network. Alternatively, distributed control lays a reliable ground to link power buffers with a minimal communication [9-11].

V. LITERATURE SURVEY

[1] **F. Ding et al.** presented detailed transient models of the grid-connected PV/Battery hybrid generation system, and all these models are simulated by using MATLAB/Simulink. PV array is firstly connected to the common dc bus by a boost converter, where the battery is also connected by a bi-directional DC/DC converter, and then integrated into the ac utility grid by a common DC/AC inverter. Maximum power point tracking helps PV array to generate the maximum power to the grid, and the battery energy storage can be charged and discharge to balance the power between PV generation and utility grid. Finally, different cases are simulated, and the results have verified the validity of models and control schemes.

[2] Lahari N V et al. studied a novel integration of wind energy from grid connected Permanent Magnet Synchronous Generator (PMSG) and solar energy systems. In order to extract maximum power from Wind energy and solar energy systems a novel technique, known as Maximum Power Point Tracking (MPPT) technique, has been adopted, in this paper. Additionally, to maintain and sustain the continuity of supply to the load on demand at all times, the outputs of wind energy and solar energy are integrated suitably. For wind generator, the overall operation is based on the estimation of the speed, that is basically a sensor-less rotor speed estimator, which in fact avoids all mechanical sensors. The rotor speed so estimated, is used to control the turbine speed by maintaining the input dc quantities (Voltage and Current) for boost converter. Simulation studies of the proposed system are carried out using MATLAB / Simulink platform, and results are presented.

[3] Ujjwal Kumar Kalla et al. presented an adaptive back propagation learning scheme for three phase four wire grid integrated solar PV - battery microgrid feeding three phase and single phase nonlinear loads simultaneously. The proposed power quality improved 3 phase 4 wire solar PV - battery micogrid is capable of delivering highly non-sinusoidal currents to nonlinear and unbalance loads of different types such that single and three phase industrial and domestic loads, while the source currents in all three phases remains balanced and sinusoidal. An adaptive back propagation learning scheme is used to control the microgrid voltage control and power quality improvement under various loading conditions through mitigation of harmonic currents, reactive power compensation and active power balancing in the system. It also improve the system power factor in highly nonlinear and unbalanced loading conditions. The proposed scheme significantly improves the steady state and dynamic performances of the 3 phase 4 wire grid integrated solar PV - battery micogrid system.

[4] Ujjwal Kumar Kalla et al. aimed at normalized neural network based control scheme for power quality improved integration of solar PV and utility grid. In the proposed scheme the solar PV and grid are integrated using a three leg voltage source converter consists of six IGBTs, three interfacing inductors and a DC bus capacitor. The neural network based scheme is used for estimating fundamental real and reactive power components of the load current in all three phases independently therefore the three phase grid current remains balanced and sinusoidal under all type of loading conditions including unbalancing in load currents of three phases. The proposed controller mitigates the harmonic current, compensates reactive power need of the system, improves system power factor and regulates the system voltage at the point of common coupling (PCC)

[5] Adikanda Parida et al. proposed an optimum rotor current control strategy considering minimum losses of the induction generator over entire period of operation is proposed. In the proposed scheme, a solar photovoltaic (PV) unit of appropriate capacity has been augmented with the rotor circuit of the DFIG along with a marginal battery backup to supplement the rotor power in order to maintain continuity of power generation. The active power fluctuations at the stator terminals of the DFIG can be minimised as both solar PV and wind energy can complement each other during lean periods of either of the sources. The proposed scheme has been simulated and experimentally validated with a 2.5 kW DFIG using dSPACE CP1104 module, which produced satisfactory results.

[6] M. A. Rosli et al. proposed a multi-input power converter (MIPC) for hybrid photovoltaic (PV) array, wind turbine (WT), fuel cell (FC) and battery storage (BT) connected AC grid network. The aim is to simplify the power system and reduce the cost. The proposed MIPC consists of a dc-dc converter and a dc-ac inverter. The output power characteristics of the PV array, WT and FC are introduced. The perturbation and observation (P&O) method is mainly used to accomplish the maximum power point tracking (MPPT) algorithm for PV array and WT sources and set FC operation power on optimal range by proton exchange membrane fuel cell (PEMFC). The MIPC is capable to operate in five modes; first to third modes occur when the power only from either renewable energy (RE) sources, fourth mode happens when power is demanded from all RE sources and finally when no power are available from all RE sources. The proposed system has been simulated by Matlab/Simulink software and the results are discussed in details.

[7] Jayasankar V N et al. provided an introduction of more power electronic devices and non-linear loads pollutes the grid and create power quality problems. Both the scarcity of energy problem and power quality problem can be simultaneously solved by using the grid interfacing inverter of renewable sources, as a shunt active filter. A suitable control strategy has to be used for giving grid interfacing inverter, the power of power quality improvement. Conventional PI controller can be replaced with a fuzzy controller for better control, and thus improve the system performance. In this paper, a grid connected hybrid system of wind-solar with power quality improvement features is simulated with a PI controller, and then results are compared by replacing PI with fuzzy controller.

VI. CONCLUSION

Renewable energy sources also called non-conventional type of energy are continuously replenished by natural processes. Hybrid systems are the right solution for a clean energy production. Hybridizing solar and wind power sources provide a realistic form of power generation. Here, a hybrid wind solar energy and fuel cell system with a converter topology is proposed which makes use of Boost Converter and controlled inverters in the design. Furthermore, a battery module is added as an energy storage system during surplus power and/or backup device during load demand. This control scheme improves the system transient voltage stability dynamically. The design of battery, wind, PV and grid converters current control with high bandwidth and the design of outer voltage loop with battery/ PV / grid converter in the inner current loop discussed. The performance of the system with designed control parameters will be verified further along with impact analysis of transient stability in DC microgrid system. A power buffer is connected in series to a power-electronics driven load and shapes the instantaneous power profile drawn from the distribution network. Renewable energy systems have been a best alternative to conventional sources. The integration of the power buffers in a hybrid system can further lead to enhancement in the power output from the grid. We can change the system modeling parameters to further improve the stability criterion.

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