A Brief Survey on Adaptive Sliding Mode Control of Different Microgrids

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Abstract-Over the previous couple of decades, dispersed generation has picked up heaps of fascination due to the naturally well disposed nature of sustainable power source, the fitting and-play activity of new generation units, and its capacity to offer low establishment cost to address the difficulties of the power showcase. DG units give power at the purpose of the load focus, which limits the misfortunes amid power transmission and enhances the power quality to the loads. Besides, it can likewise be utilized as a reinforcement source under the nonappearance of grid. But the major drawback of the battery in stand-alone PV systems is its cost factor and the bulky size. So the battery needs to be properly designed to obtain the optimal efficiency from the PV system.

Keywords-Standalone microgrid, renewable energy source, Photo voltaic (PV) generation.

I. INTRODUCTION

The PV generation can be generally divided into two types: stand-alone systems and grid-connected systems. Since PV modules are easily transported from one place to another, it can be operated in stand-alone mode in remote areas where the grid is not reachable or is not economical to install. This system can also suitable for telecommunications units, rural electricity supply, and also auxiliary power units for emergency services or military applications. Most PV systems were stand-alone applications until mid-90. A typical stand-alone PV system comprises of a solar array and a storage device. The storage devices include batteries, flywheels, super-capacitors, pumped hydroelectric storage and super-conducting magnetic energy storage devices. Since the solar energy is not possible throughout the day, a storage device is needed as a backup device in order to make the electricity available whenever it is needed. Batteries are commonly used in PV system as a storage device.

Electrical power (i.e. direct current or DC) generation from freely available Sun light is a feasible solution using solar PV generation system. Sun's irradiation is direct source of photon energy, which is converted to electrical energy by semiconductor technology based PV cells. PV cells are nothing but p-n junction diodes exposed into Sunlight. These cells are combined together for building larger PV systems to meet the power requirement. Though the PV based DGs are excellent choice for microgrid applications, yet the initial installation cost for such DGs is high. But in a long run (up to 30 years) these DGs are more economical, especially when the size of the installation is small or medium (less than 5 MW). Another challenge in PV based generation is low conversion efficiency.

Solar energy can be harnessed using different technologies some of them are solar cells, photovoltaic cells, solar fibers, solar ponds, solar upward design and energy tower. PV cells work with the same principle of PN junction. PV cells are made up of two layers positive and negative layer with a barrier between them. When photons (obtained from the sun's radiation) falls on the solar cells would create a free electron, hence would result in potential difference. Each PV cell produce very less energy , hence a number of cell combine together to form a PV module and several modules combine together to form PV.

Wind is caused by uneven heating of the atmosphere by the sun, irregularities in the earth's surface and rotation of the earth. The kinetic energy from the wind is transformed to electric energy or mechanical energy. Wind turbines can be basically classified into two they are horizontal axis and vertical axis turbines.For an understanding of wind turbine power equation considered first power extraction by means of a device, which is easily understood. A circular disc of area A is mounted on a trolley. It blows with velocity v and the trolley runs in with average speed u in the wind direction.

Another possibility to take advantage of the PV system is injecting the PV power directly into the existing utility grid. In most parts of the industrially developed world grid electricity is readily available and can be used as a giant battery to store all the energy produced by the PV cells. The PV power first supply to the local load and the rest surplus power is feeding into the grid for the use of other customers. As a result, the burden on the conventional generation units (e.g. thermal power plant) is reducing. When the PV power is not sufficiently available (at night or on cloudy days), then the utility grid can provide power from conventional sources. Removing the battery from the PV system not only make the system economical but also increases its reliability. Generally, the lifetime of a PV cell is more than 20 years, whereas a battery lasts for at most five years and also needs periodic maintenance.

A grid-connected photovoltaic (GPV) system comprises a group of energy transducers, i.e., PV panels and dc-dc converter which converts dc power from PV panel side voltage to required dc bus voltage. While a dc-ac converter is used as a power interfacing between the dc PV panels and the ac grid. The dc-ac power processing stage is achieved by feedback controlled inverter systems. This inverter must guarantee that it will inject the current into the grid at unit power factor with the lowest harmonic distortion level. Therefore, PV inverters have an enormous impact on the performance of PV grid-tie systems. One of the most active area of research for GPV system deals with the way in which the elements of the GPV inverter, PV panels and power converter stage or stages are arranged to transfer the PV power to the utility grid efficiently.

II. STANDALONE PV SYSTEM

The standalone PV system is commonly used in remote areas where the grid is not reachable or is not economical to install. This system can also be suitable for telecommunications units, rural electricity supply, and auxiliary power units for emergency services or military applications. As the solar energy is only possible during the daytime, it is very much necessary to store the energy for the night or for cloudy days. A standalone PV system uses lead-acid rechargeable batteries, as the storage device. A basic block diagram of standalone PV system with battery as storage element is shown in Figure 2.1. As battery plays an important role in this mode of operation, so modeling is required to design its charging and discharging control.

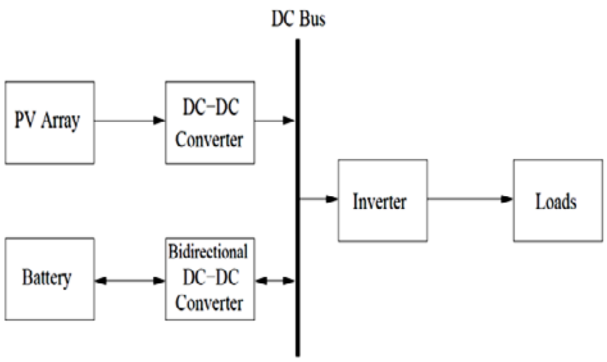

Fig. 2.1 Standalone PV systems with battery load.

Micro grid is an important and necessary part of the development of smart grid. The micro grid is characterized as the "building block of smart grid". It comprises low voltage (LV) system with distributed energy resources (DERs) together with storage devices and flexible loads. The DERs such as micro-turbines such as, fuel cells, wind generator, photovoltaic (PV) and storage devices such as flywheels, energy capacitor and batteries are used in a micro grid. The micro grid can benefit both the grid and the customer.

The single phase grid interactive inverter system is shown in Fig. 2.2. It comprises of a dc supply voltage E, a full bridge VSI, an LCL filter with local loads and a utility grid of voltage vg. The LCL filter composes of the inverter side inductor L1, capacitor C, and a grid interfacing inductor L2 connected through a static transfer switch (STS). The local sensitive loads are generally connected with the filter capacitor in a parallel manner. The switches of the bridge inverter are controlled by the FFHC control logic, which is implemented by means of a cascaded feedback controller. The currents i1 and i2 are called the filter inductor current and grid interfacing current (termed as grid current in this paper) respectively.

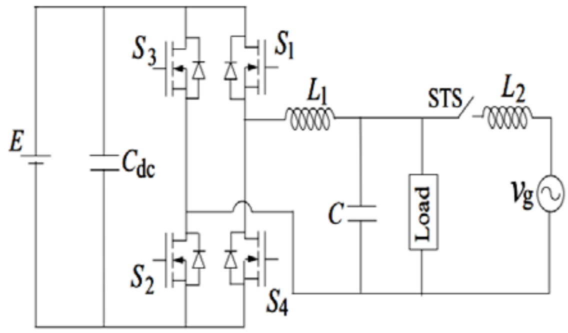

Fig. 2.2 Single Phase Micro Grid System.

Sliding Mode Control (SMC) is a nonlinear control method, belonging to the framework of Variable Structure Control (VSC), that adjusts the dynamics of systems by the application of a switching control The basic concept is the design of a controller ensuring finite-time arrival of the state space trajectory to a suitable surface in both its sides. This implies the generation of the so-called "sliding motion" on that surface. The latter is named switching surface and the sliding motion can occur on one or more than one surfaces defined in the state space of the controlled system. When the sliding motion is contemporarily enforced on all the defined surfaces, the controlled system is said to be in "sliding mode".

Given some initial conditions x0 = x(t0), the goal of SMC is to steer the state trajectories of the controlled system to the so-called sliding subspace or sliding manifold, i.e., the intersection of the switching surfaces, in order to enforce a sliding mode. If this is the case, the states belong to the sliding subspace, and the controlled equivalent system features an order reduction. Moreover, the dynamic performance can be arbitrarily specified by suitably selecting the sliding manifold, and it is invariant with respect to a significant class of parameter uncertainties and disturbances.

III. LITERATURE SURVEY

Sr. no.	Title	Author	Year	Approach
1	Adaptive Sliding Mode Control of Standalone Single-Phase Microgrid Using Hydro, Wind, and Solar PV Array-Based Generation	U. K. Kalla, B. Singh, S. S. Murthy, C. Jain and K. Kant	2018	This paper presents an adaptive sliding mode control (ASMC) of an improved power quality standalone single phase microgrid system. The proposed microgrid system integrates a governor-less micro-hydro turbine driven single-phase two winding self-excited induction generator with a wind driven permanent magnet brushless dc generator, solar photo-voltaic (PV) array and a battery energy storage system.
2	Simple model for understanding harmonics propagation in single-phase microgrids	G. Kulia, M. Molinas, L. M. Lundheim and O. B. Fosso	2017	This paper presents an analytical method developed to explain the mechanism of harmonic transfer between the ac and dc sides of a single-phase inverter in a PV microgrid. The model explains how the feed-forward of the current from the ac side of the PV-inverter into the control system, causes even harmonics on the dc voltage.
3	Single-phase power conditioning system with slew-rate controlled synchronizer for renewable energy system in microgrid	S. Heo, W. Park and I. Lee	2016	This paper proposes single-phase power conditioning system which is capable of connecting a microgrid to an utility grid seamlessly through slew-rate control.
4	Control of standalone Wind/PV hybrid renewable power generation	T. Maity, S. Kakkar and R. K. Ahuja	2016	his paper proposes effective control of PV/Wind hybrid generation scheme using solar and wind energy for the stand alone applications. The system consists of PV/Wind hybrid system, Cuk Sepic dc-dc converter, a three phase dc to ac converter, controller and ac load
5	Hybrid Three-Phase/Single-Phase Microgrid Architecture With Power Management Capabilities	Q. Sun, J. Zhou, J. M. Guerrero and H. Zhang	2015	This paper proposes a hybrid microgrid architecture and its power management strategy. In this microgrid structure, a power sharing unit (PSU), composed of three single-phase back-to-back (SPBTB) converters, is proposed to be installed at the point of common coupling.
6	Power quality control strategy for grid-connected renewable energy sources using PV array, Wind turbine and battery	L. Djamel and B. Abdallah	2013	This paper proposes an effective power quality control strategy of renewable energy sources connected to power system using photovoltaic (PV) array and battery.
7	An Adaptive Sliding Mode Controller for enhanced Q'-V droop in a microgrid	C. N. Rowe, T. J. Summers, R. E. Betz and T. G. Moore	2012	This paper introduces an adaptive sliding mode voltage controller that is able to increase the power control loop bandwidth.

U. K. Kalla, B. Singh, S. S. Murthy, C. Jain and K. Kant [1] This paper presents an adaptive sliding mode control (ASMC) of an improved power quality standalone single phase microgrid system. The proposed microgrid system integrates a governor-less micro-hydro turbine driven single-phase two winding self-excited induction generator with a wind driven permanent magnet brushless dc generator, solar photo-voltaic (PV) array and a battery energy storage system. These renewable energy sources are integrated using only one single-phase voltage source converter (VSC). The ASMC-based control algorithm is used to estimate the reference source current which controls the single-phase VSC and regulates the voltage and frequency of the microgrid in addition to harmonics current mitigation. The proposed ASMC estimates the reference real and reactive powers of the system, which is adaptive to the fluctuating loads. The sliding mode control is used to estimate the reference real power of the system to maintain the energy balance among wind, micro-hydro, solar PV power, and BESS, which controls the frequency of standalone microgrid. The proposed microgrid is implemented in real time using a digital signal processor controller. Test results of proposed microgrid shows that the grid voltage and frequency are maintained constant while the system is following a sudden change in loads and under intermittent penetration of wind and solar energy sources.

G. Kulia, M. Molinas, L. M. Lundheim and O. B. Fosso [2] This paper presents an analytical method developed to explain the mechanism of harmonic transfer between the ac and dc sides of a single-phase inverter in a PV microgrid. The model explains how the feed-forward of the current from the ac side of the PV-inverter into the control system, causes even harmonics on the dc voltage. It further shows how the controller's feedback of the dc bus voltage carrying even harmonics results in odd harmonics on the ac side of the PV-inverter. This harmonic propagation model is verified with a simulation of the PV microgrid system. The results of this simulation study provides consistency by proving that odd harmonics on the ac voltage causes even harmonics on the dc bus, and that even harmonics on the dc bus again causes more odd harmonics on ac voltage.

S. Heo, W. Park and I. Lee [3] This paper proposes single-phase power conditioning system which is capable of connecting a microgrid to an utility grid seamlessly through slew-rate control. The power conditioning system is composed of a single-phase phase-locked loop using an inverse Park transformation to detect the grid phase, a phase synchronizer using the slew-rate control, and isolated bidirectional inverter which transfers power among the utility grid, energy storage, and load. The inverter is controlled by the voltage and current controllers for the island and grid-connected operation, respectively. The power conditioning system operates using the inverter controlled by a mode controller according to the microgrid operation mode and state of charge of the energy storage. The stable operation of the power conditioning system was verified in three microgrid operation modes through simulations using the MATLAB/Simulink tool.

T. Maity, S. Kakkar and R. K. Ahuja [4] Renewable energy sources such as solar and wind are ubiquitous and environmental friendly. The Hybrid PV/Wind power system is the best renewable energy sources due to their complementary nature. This paper proposes effective control of PV/Wind hybrid generation scheme using solar and wind energy for the stand alone applications. The system consists of PV/Wind hybrid system, Cuk Sepic dc-dc converter, a three phase dc to ac converter, controller and ac load. The dc voltage magnitude of the PV array is boosted to a higher value by using Cuk-SEPIC converter before converting ac voltage. This Cuk-SEPIC converter can supply the load depending on the source of power available i.e from wind or PV or both of them. As solar power is intermittent in nature, so tracking the maximum power point (MPP) of a PV array is usually an essential part of a PV system. Specialized control algorithms have been developed called maximum power point tracking (MPPT) to constantly extract the maximum amount of power from the array under varying conditions. In this paper Perturb and Observe (P&O) method is used for maximum power point tracking. A three phase pulse width modulated inverter is used to convert dc to ac and to supply power to ac loads. A synthesized AC output voltage is produced by appropriately controlling the switches using PWM technique using average power control to control active and reactive power fed to the load. The average power control method provides high quality sinusoidal output current and controls the average power flow. The performance of the system is analyzed using MATLAB/SIMULINK.

Q. Sun, J. Zhou, J. M. Guerrero and H. Zhang [5] With the fast proliferation of single-phase distributed generation (DG) units and loads integrated into residential microgrids, independent power sharing per phase and full use of the energy generated by DGs have become crucial. To address these issues, this paper proposes a hybrid microgrid architecture and its power management strategy. In this microgrid structure, a power sharing unit (PSU), composed of three single-phase back-to-back (SPBTB) converters, is proposed to be installed at the point of common coupling. The aim of the PSU is mainly to realize the power exchange and coordinated control of load power sharing among phases, as well as to allow full utilization of the energy generated by DGs. Meanwhile, the method combining the modified adaptive backstepping-sliding mode control approach and droop control is also proposed to design the SPBTB system controllers. With the application of the proposed PSU and its power management strategy, the loads among different phases can be properly supplied and the energy can be fully utilized, as well as obtaining better load sharing. Simulation and experimental results are provided to demonstrate the validity of the proposed hybrid microgrid structure and control.

L. Djamel and B. Abdallah [6] The output power from renewable energy sources fluctuates because of weather variations. This paper proposes an effective power quality control strategy of renewable energy sources connected to power system using photovoltaic (PV) array and battery. A

Battery is connected to the DC bus of PV power generation system for power quality control of the grid-connected renewable energy sources. The results of a power-hardware-in-the-loop simulation demonstrate the effectiveness of the proposed control method. The system not only enhances the reliability of renewable energy systems, but also improves the availability of PV systems.

C. N. Rowe, T. J. Summers, R. E. Betz and T. G. Moore [7] The state of the art power balancing control utilized in microgrids is known as `Power Frequency Droop'. Contemporary power frequency droop schemes utilise Proportional Integral (PI) controllers for voltage magnitude control. The power quantity directly coupled to the voltage is Q' (Q-dash power). Q' is present in, and affects, the error signal of the PI voltage controller. The controller is acting on two input signals, voltage and Q'. To avoid control interactions, the filtering applied to Q' must be significantly slower than the filtering applied to the voltage. Thus the need to avoid control interactions leads to decreased bandwidth of the power control loop. This paper introduces an adaptive sliding mode voltage controller that is able to increase the power control loop bandwidth. The effectiveness of the control scheme is proven by results presented from SABER®simulations and a dSPACE®hardware system consisting of two inverters.

IV. PROBLEM IDENTIFICATION

Very much exploitation and research for new power was done not only in the area of nuclear power generation but also in the area of unlimited energy sources such as solar power generation, wind power generation etc. The renewable energy sources like solar and wind have shown promise as possible cost efficient alternatives to fossil fuels. Compared to wind energy, the most effective and harmless energy source is solar energy. Most renewable sources are based on energy from the Sun, geothermal forces and planetary motion in the solar system. Solar, wind, small hydro power, wave energy, tidal power, ocean thermal energy conversion, and bio fuels are renewable where as fossil fuels constitute non- renewable.

V. CONCLUSION

In this survey paper study of Adaptive Sliding Mode Control of Standalone Single-Phase Micro grid Using Hydro, Wind and Solar PV Array Based Generation. The distributed generation framework powered by the PV source is regularly utilized, for its low establishment and running expense. By and by, the vitality provided by the PV source is around 1% of the world vitality utilization. In the course of recent years, sun based power sources request has become reliably because of the accompanying variables: expanding productivity of sunlight based cells; fabricating innovation enhancement; economies of scale; and can be introduced all over the place. The above factors are making PV system a good candidate to be one of the most important renewable energy sources of the future.

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