An Extensive Literature Review on Grid-Connected Photovoltaic Systems

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Abstract - The rapid economic growth of any country requires the injection of large amounts of energy and since energy cannot be created, it is necessary for every country to diversify its sources of energy. Energy is the ability to do work and therefore it is the basic requirement for achieving all tasks. There are many forms of energy which include; mechanical (potential and kinetic) energy, chemical energy, electrical energy, etc. The desirability and usefulness of electrical energy to the world cannot be overemphasized. Electrical energy is useful in industrial, commercial and residential establishments. Electrical energy is useful in all manufacturing, telecommunications, residential (lighting, heating, cooling, entertainment) and commercial activities. Performance and reliability are essential to the PV system with a considerable power scale and voltage level. Therefore, proper modeling and control design allows for progress on hardware implementation. The whole PV system can be divided into several subsystems to facilitate the control individually. First of all, in the multi-string grid connected photovoltaic (PV) system, equivalent circuit is modeled to represent the PV arrays.

Keywords: PV System, Power Quality Improvement.

I. INTRODUCTION

Photovoltaic (PV) sources are used nowadays in many applications as they own the advantage of being maintenance and pollution free. In the past few years, solar energy sources demand has grown consistently due to the following factors: 1) increasing efficiency of solar cells; 2) manufacturing technology improvement; and 3) economies of scale. Meanwhile, more and more PV modules have been and will be connected to utility grid in many countries. Now the largest PV power plant is more than 100MW all over the world. Furthermore, the output of PV arrays is influenced by solar irradiation and weather conditions. More importantly, high initial cost and limited life span of PV panels make it more critical to extract as much power from them as possible. Therefore, maximum power point tracking (MPPT) technique should be implemented in DC/DC converter to achieve maximum efficiency of PV arrays. Several algorithms have been developed to achieve MPPT technique. As the capacity of PV system growing significantly, the impact of PV modules on power grid can't be ignored. They can cause problems on the grid like flicker, increase of harmonics, and aggravated stability of the power system. To both increase the capacity of PV arrays and maintain power quality, it's necessary to comply with the technique requirements of the PV system, such as fault-ride-through capability and harmonic current regulation. Especially when a large scale PV module is connected to the grid, the effects on the grid may be quite severe. Therefore, the system operation and system stability under fault conditions should be examined when PV modules are interface with power grid.

Increasing use of static power converters like rectifiers and switched mode power supplies causes injection of harmonic currents into the distribution system. Current harmonics produce voltage distortions, current distortions, and unsatisfactory operation of power systems. Therefore, harmonic mitigation plays an essential role in grid connected PV system. This standard helps to prevent harmonics from negatively affecting the utility grid. In this research, as well as supplying active power, PV inverter can be controlled to provide harmonic currents needed by nonlinear loads so that the current on the grid side can be approximately sinusoidal, at least complies with the IEEE Std. 519. This concept is simulated successfully in the simulation environment. Then, the test bed is constructed and the components required consist of: a DC power source, a DC/AC inverter, a LC filter, and a grid voltage supply. Once validated the hardware test could provide useful insight into future test in power system at a higher power level.

II. SYSTEM DESCRIPTION

Harmonic Compensation

PV system can compensate the harmonics generated by the nonlinear loads as well as supply active power to the power grid. The simulation scheme is established in PSCADTM as shown in Fig. 1.

The grid voltage is supposed to be balanced and simulated as an ideal voltage source. And the solar arrays and grid are supplying power to the diode rectifier in parallel with resistive load. The load current is very rich in harmonics and the inverter is controlled to provide harmonic compensation.

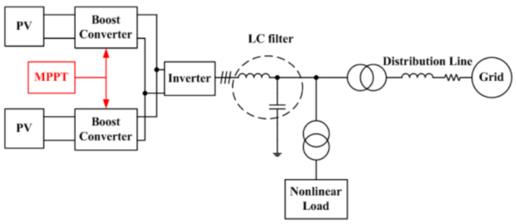

Fig. 1: Grid-connected PV system with function of harmonic compensation

A multi-string grid-connected PV system with the function of harmonic compensation is presented in PSCAD/EMTDCTM simulation environment. The scheme of the system is demonstrated in Fig 2. However, the transformers are not represented in the hardware configuration due to the fact that no large-scale transformer is needed at a low voltage level. But, a variable transformer is needed to step down the utility voltage to the required voltage level. Moreover, the transmission line is not considered in this hardware since the resistance and inductance have been included in both LC filter and connection wires. Because the PV arrays are not available in the laboratory, a controllable DC source is instead used to emulate the characteristic of PV arrays. A modified hardware scheme is then designed for validation, which is shown in Fig. 2.

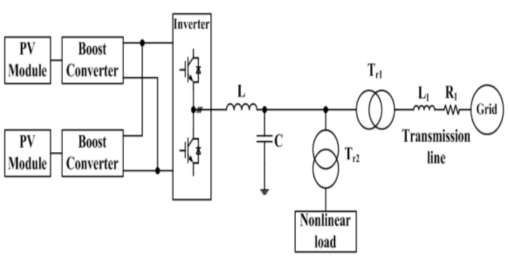

Fig. 2: Overall structure of PV system with active power filter

III. LITERATURE REVIEW

In the year of 2014 Mahmud, M.A.; Pota, H.R.; Hossain, M.J.; Roy, N.K.,[1] in the study of a robust stabilization scheme for a three-phase grid-connected photovoltaic system to control the current injected into the grid and dc-link voltage to extract maximum power from photovoltaic (PV) units. The scheme is mainly based on the design of a robust controller using a partial feedback linearizing approach of feedback linearization, where the robustness of the proposed scheme is ensured by considering uncertainties within the PV system model. In this paper, the uncertainties are modeled as structured uncertainties based on the satisfaction of matching conditions. The performance of the proposed stabilization scheme is evaluated on a three-phase grid-connected PV system in terms of delivering maximum power under changes in atmospheric conditions.

In the year of 2013 da Silva, A.R.; Sup, F.,[2] presents to the preliminary design results and control strategy of a two-wheeled inverted pendulum (TWIP) robotic walker for assisting mobility-impaired users with balance and stability. A conceptual model of the vehicle is developed and used to illustrate the purpose of this study. Motor dynamics is considered and the linearized equations of motion for the system are derived using Newtonian mechanics. In order to eliminate the effects of loop interaction and impose the desired dynamics on the system, a decoupling control scheme was implemented. Upright stabilization of the robotic walker is achieved using linear quadratic regulator (LQR) control. Improved disturbance rejection is achieved through the implementation of a pitch controller. Simulation results demonstrate that a robustly tuned pitch controller can mitigate effect of disturbance on the linear displacement of the vehicle by as much as 74%.

In the year of 2012 Amini, H.; Mirrahimi, M.; Rouchon, P.,[3] in the study of A feedback scheme, stabilizing an arbitrary photon-number state in a microwave cavity, is analyzed. The quantum non-demolition measurement of the cavity state allows in open-loop a non-deterministic preparation of photon-number states. By the mean of a controlled classical field injection, this preparation process is made deterministic. The system evolves through a discrete-time Markov process and the feedback law relies on Lyapunov techniques. This feedback design compensates an unavoidable pure delay by a stochastic version of a Kalman-type predictor. After illustrating the efficiency of the proposed feedback law through simulations, the global closed-loop convergence is proved. It relies on tools from stochastic stability analysis. A brief study of the Lyapunov exponents of the linearized system around the target state gives a strong indication of the robustness of the method.

In the year of 2012 Jiang Yu; Zhang Yingchun; Jin Jing,[4] presented to a configuration scheme of multiple MEMS reaction wheels for CubeSat. In this configuration three pairs of arrays of MEMS reaction wheels are installed symmetrically within the CubeSat's surface, wherein each array is composed by 4 × 4 co-rotating elements. Through counter-rotating of each pair of symmetrical arrays three zero momentum wheels are achieved. Assuming that control moment of MEMS reaction wheel have on-off form, two attitude control methods are designed. When change of angle is very small for attitude stabilization, constraints set of the disturbance and state is described as polytope, and constraint tightening method is used to design control law for linearized attitude equation. When performing large angle for attitude maneuver, an extended state observer is designed to estimate the disturbances. For predicting the attitude angle, the fliess expansion method of nonlinear attitude equation is proposed. The optimal control law is obtained by solve minimum of attitude predicting error finite times. Simulation results show the effectiveness of the proposed methods.

In the year of 2011 Kadam, S.N.; Seth, B.,[5] in the study of Reactobot is a one-wheel robot developed at IIT Bombay. It is balanced by reaction wheel actuator suspended from the central axis. The Robot can get accelerated in forward or backward direction by pitching the pendulum mass within the wheel in the same direction. Turns can be- executed by tilting robot to right or left while in motion. In this paper, we describe multi-body dynamic model of the Reactobot. The mathematical model of Reactobot is developed using the Lagrangian constrained generalized formulation. Dynamic model is highly nonlinear and Jacobian linearization has been used to obtain a linear model for operation close to vertical rolling motion. LQR control scheme is proposed to design controller for linearised model. Simulation results demonstrate the effectiveness of this scheme.

In the year of 2011 Csernak, G.; Stepan, G.,[6] describe to It is well-known that nonlinear terms in the governing equations of dynamical systems may lead to chaotic behaviour. With this fact in mind, a well-trained engineer must be able to decide which system of equations can be linearized without a significant change in the solution. However, if the linearized dynamical system in question is part of a digital control loop, the interaction between the original mechanical or electrical system and the control system may still lead to un expected behaviour due to the so-called digital effects. The goal is to analyze the problem of computer-controlled stabilization of unstable equilibria, with the application of the PD control scheme. Authors consider the problem of the inverted pendulum, with linearized equations of motion. As a consequence of the digital effects, i.e., the sampling and the round-off error, the solutions of the system can be described by a two dimensional piecewise linear map. Authors how that this system may perform chaotic behaviour. Although the amplitude of the evolving oscillations is usually very small, several disconnected strange attractors may coexist in certain parameter domains, rather far from the desired equilibrium position. Authors claim that since the amplitude is small the nonlinearity of the digital control system is the primary source of the stochastic-like vibrations of the inverted pendulum, instead of the nonlinearity of the mechanical system.

In the year of 2011 Thorne, C.E.; Yim, M.,[7] in the study of Micro air vehicles have emerged as a popular option for diverse robotic and teleoperated applications because of their inherent stealth, portability, and disposability. In this work, they adopt a system-level perspective for the development of a rotary-wing micro air vehicle and propose a new design that utilizes gyroscopic dynamics for attitude control. Unlike traditional vehicles where attitude control moments are generated by aerodynamic control surfaces, the proposed vehicle will leverage the existing angular momentum of its rotating components to generate gyroscopic moments for controlling attitude. The capacity to rapidly generate large gyroscopic control moments, coupled with the precision gained from eliminating the need for complex and restrictive aerodynamic models, improves both agility and adaptability. Authors present the design and analysis of a new flying machine including the dynamic model with simplified aerodynamics and a control scheme based on a model linearized around hover. Simulations show the responsiveness and stabilization of a simple linear controller for hover

In the year of 2010 Zhao Zhan-shan; Zhang Jing; Sun Lian-kun; Ding Gang,[8] describe to An Integral sliding mode based on the finite time stabilization control scheme for the longitudinal dynamics of aircraft is proposed in this paper. The Input/Output Linearization technique is applied for control design to linearize the dynamics of aircraft with respect to air speed V and altitude h. Simulation studies demonstrate that the proposed controller is robust with respect to the perturbation.

In the year of 2010 Sang-Hyun Park; Chong-Won Lee,[9] in the study of, there has been an increasing need for development of active magnetic bearing (AMB) systems of smaller size and lower energy consumption than ever, as AMBs seek for applications in compact, portable rotating machines such as hard disk spindle and artificial heart blood pump. Among others, the three-pole AMB configuration turns out to be more profitable in terms of compactness in design and low power loss than the conventional four- or eight-pole AMB. However, one of the inherent drawbacks in controller design of three-pole AMB is the strong coupling in magnetic flux between magnetic poles. It leads to the strongly nonlinear system behavior, when the equation of motion is formulated in the conventional Cartesian coordinates. In this research article propose use of the redundant bearing coordinates to describe the three-pole AMB system behavior, so that the potential difference controllers can be easily designed, based on the decoupled linearized control model for each pole. The proposed method is applied to control of a five-axis AMB system, which consists of a three-pole radial AMB for stabilization in the radial direction and a ring-type permanent magnet bearing for levitation in the axial and tilt directions. It is shown that simplistic equation of motion for the five-axis AMB system can be derived in the proposed redundant bearing coordinates and the resulting control equations become completely decoupled. Experiments are also carried out with the five-axis disk-type AMB system equipped with Hall diodes for measurement of the radial displacement and it is confirmed that the proposed control scheme succeeds in the run-up test.

IV. PROBLEM IDENTIFICATION

Robust stabilization scheme is considered by modeling the uncertainties of a three-phase grid-connected PV system based on the satisfaction of matching conditions to ensure the operation of the system at unity power factor. In order to design the robust scheme, the partial feedback linearization approach is used, and with the designed scheme, only the upper bounds of the PV systems' parameters and states need to be known rather than network parameters, system operating points, or nature of the faults. The results may be improved further for better system efficiency. The resulting robust scheme enhances the overall stability of a three-phase grid connected PV system, considering admissible network uncertainties. Thus, this stabilization scheme has good robustness against the PV system parameter variations, irrespective of the network parameters and configuration.

V. CONCLUSIONS AND FUTURE SCOPE

In all the control strategies, compensating current is controlled using SM control or PFL based control. SM control strategy is applied to APF considering the dynamic model of APF similar to that of model reported. But PFL based control is applied to shunt APF considering its averaged dynamic model. The averaged dynamic model of both single phase and three phase shunt APF is obtained by averaging coupling inductor current and filter capacitor voltage over a complete switching cycle. Both SM current control strategy and PFL based current control strategy are found robust and easy to implement. But PFL based controller is found more suitable than the SM controller as it improves the performance of APF by analysing the stability of the complete system. It is also observed that reference source current calculation method has an important role in improving the performance of APF. Simulations may be done in MATLAB platform.

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