ABSTRACT

The main objectives of this work are to analyze, design, and assess the performance on a set of robust controllers for the Variable Structure Systems (VSS). VSS are the nonlinear physical systems with impacts such as switching circuits in power electronics and lightly damped mechanical systems with impacts. The study is performed on three VSS namely, DC-DC buck converter, single phase full bridge rectifier and a cart based inverted pendulum.

Only conventional controllers like Proportional, Proportional-Integral and Proportional-Integral-Derivative controllers were employed for the control of Variable Structure Systems conventionally. However, they often fail to perform satisfactorily under large parameter load variations. Hence, with the objective of attaining better performance under parameter and load variations, Sliding Mode (SM) controller was introduced to VSS. However, there is a slight drawback with conventional SM controlled VSS, i.e. their dynamic and steady state performances deteriorate if the loading condition differs from the nominal condition. When operated below the nominal load, there will be overshoots and ringing during transient. When operated above the nominal load, the response will be slow with a high steady state error. Therefore, an alternate to SM controller which can optimize the dynamic performance of the VSS during load variations, is proposed in this thesis.
First the work is, to design an advanced controller which includes the features of feed forward controller based on Posicast element for the buck converter. Posicast is a feed forward compensator that eliminates overshoot in system response, but the traditional approach is sensitive to variations in natural frequency. The new hybrid method described here reduces the undesirable sensitivity by using Posicast within a feedback loop. Compared to classical Proportional–Integral–Derivative (PID) control, the new control results in lower noise in the control signal because the controller has a lower gain at high frequency. Furthermore, the new controller is less sensitive to the inherent time delay. This hybrid approach is a straightforward method to design controller parameters from the small-signal averaged model of the converter dynamics. The proposed control system is compared with the classical PID control of a buck DC-DC converter.

This work also discusses the design of an Interconnection-and-Damping Assignment Passivity- Based Control (IDA-PBC) for a full-bridge rectifier. The closed-loop system performance fulfils unity power factor in the AC mains and output DC voltage regulation. The controller design takes advantage of the Generalized State Space Averaging (GSSA) modeling technique to convert the quoted non-standard problem (in actual variables) into a standard regulation one (in GSSA variables). In this approach, the output current is the measured variable instead of the line current and the number of sensors does not increase in comparison with traditional approaches. The whole system is robust with respect to load variations.
Using the GSSA modeling, it is possible to describe the control objectives, namely load voltage regulation and unity power factor at the input AC mains, as a regulation problem. Common solutions require the sensing of input voltage, line current and output voltage. Achieving robustness to load variations is not a simple control problem because whenever load varies, the amplitude of the line current must change to a new value to keep DC voltage regulation, but keeping the control objective over the line current shape. It is difficult to treat this problem as a tracking problem without measuring the load since the line current reference depends on it.

The main contributions of this approach are: first, a tracking problem is solved in a PCH (Port-Controlled Hamiltonian) framework. Using GSSA model it is possible to transform the non-standard tracking control problem into a regulation one. Second, the extension of the Hamiltonian structure of the nonlinear model to the GSSA model and finally, the control strategy is designed.

Finally, another objective of this work is to design a complete control system for the swing-up and stabilizing control of cart - inverted pendulum. In particular, this work outlines the effectiveness of a particular Swing-up method based on feedback linearization and Total Energy Shaping (TES). The basic idea to solve the problem of driving the pendulum from down or any to upright position has been always to inject the necessary energy to do it. The power of modern state-space techniques for the analysis and control of SIMO (Single-Input Multi-Output) systems is also analyzed and state-feedback controller is employed for stabilizing the inverted
pendulum. Thus, the stabilization approach consists in a first step that stabilizes the down subsystem via kinetic energy shaping and a second step extends the solution to the upper subsystem via forwarding technique and the effectiveness of this control method is confirmed by comparing the results with the performance of Sliding Mode Controller. The design analysis has been done in simulations on the nonlinear mathematical model of the inverted pendulum.