Synopsis Seminar

Seminar Title	: Advanced Control Techniques for Fuel Cell Integrated Boost Converter
Speaker	: Nitesh Agrawal (Rollno : 517ee6004)
Supervisor	: Susovon Samanta
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Abstract : Growing concern about reducing carbon emissions has prompted major global economies to seek out alternate energy sources such as renewable and hydrogen energy. When compared to solar photovoltaic and wind energy, fuel cells have been shown to be effective alternatives to renewable energy for portable and stand-alone applications. The proton-exchange membrane fuel cell (PEMFC) has been determined to be the most appropriate for standalone applications among the several FC classifications. As an electrochemical source of power, FCs only produce waste that is barely harmful to the environment. A power electronic interface becomes an intrinsic part of the system due to the multi-physics structure, non-linear V-I characteristics, and low output voltage of FCs. Furthermore, the controlling property of FCs is stack current, which determines the level of stack voltage, hydrogen flow, and temperature rise. Because of its simple structure, ability of current control, and primary function of pumping up voltage, a boost converter is an excellent choice. However, designing a controller for such an integrated system imposes various challenges.

Various types of controllers were investigated in this study in order to accomplish the required performance, reduce the issue of the output capacitor's effective series resistance (ESR), and optimize the control effort. Apart from the average current mode controller, the state-feedback structure has demonstrated faster and more accurate performance as its tuning is simpler. A wide range of tuning methodologies based on pole-placement and regulation cost minimization have been explored. Pole-placement based methods can be subdivided into two major categories, viz, user-defined and standard form. The former method puts no restriction as the poles can be placed according to the performance specifications. While the latter restricts the placement as the bounds are based on the fixed standard form polynomial, such as ITAE, Butterworth's, and Bessel's. However, these method do not guarantees the optimal performance. A classical linear quadratic regulator (LQR) based cost function has been imposed using the converter dynamics for optimal performance and minimal control effort. Due to the structural property of state-feedback and ESR of the output capacitor, an offset error in the output voltage will be observed when the operating points are changed. To address this issue, the first modification (m-LQR) has been proposed, which minimizes the offset error. In addition, state-feedback uses the fixed reference inductor current, due to which the state trajectories never terminate at the origin. To widen the range of dynamic loading and minimize control effort, a second modification on LQR (M-LQR) is proposed.

Alternatively, to address the issue of steady-state error, an integrator is augmented with the system. This structural alteration remains in the state-feedback architecture with additional order. Tuning of the coefficient for state-feedback with an integrator has also been carried out using earlier methods of pole-placement and optimal tuning. As this structure does not produce any steady-state error, and also optimally tuned coefficient forces trajectories to travel with the least past. Therefore, the coefficient of state-feedback with integral structure is then mapped to coefficients of conventional average current mode controller, and its variants such as I^2 current mode controller, V^2 current mode controller, and the proposed M-LQR controller. As the tuning of this architecture consumes an ample amount of designers' effort and does not even guarantee the exact performance. This methodology can be useful for quick tuning of the mapped controller.

Furthermore, the aforementioned and proposed linear controllers have the limitation of addressing the nonlinear disturbance injected into the system. These disturbances are different than that of noise, which can not be filtered out and remains there. To address this issue, a sliding mode controller based on linear optimal surface is proposed. It is found that the effectiveness of the linear controller has improved with the addition of a sliding mode control.

All the control algorithms developed in the thesis have been verified using simulation and validated through experimentation.