Project Report EE665 (group number 14) design a FCS MPC based bi-directional buck boost converter

submitted

by

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1 Contribution

1.1 Name: Ranjeet Kumar

- Did the circuit diagram in visio.
- Studied about bidirectional buck boost converter.
- Studied some previous year research papers about FCS MPC control tecnique
- Documentation of report in Latex

2 Chapter 1: Design a FCS MPC based bidirectional buck boost converter

2.1 Objectives

- To accurately regulate the power flow direction and magnitude in both buck and boost modes,it makes energy transfer between source and load efficiently.
- It optimizes switching patterns and minimize losses to achieve high overall efficiency across various operating conditions.
- It seamlessly switch between buck and boost modes to avoid abrupt changes in output voltage or current, improving system stability and preventing transients.
- FCS-MPC allows balancing multiple objectives like efficiency, voltage regulation, and current limiting simultaneously, providing more flexibility and control over the converter's behavior

2.2 Schematic block diagram

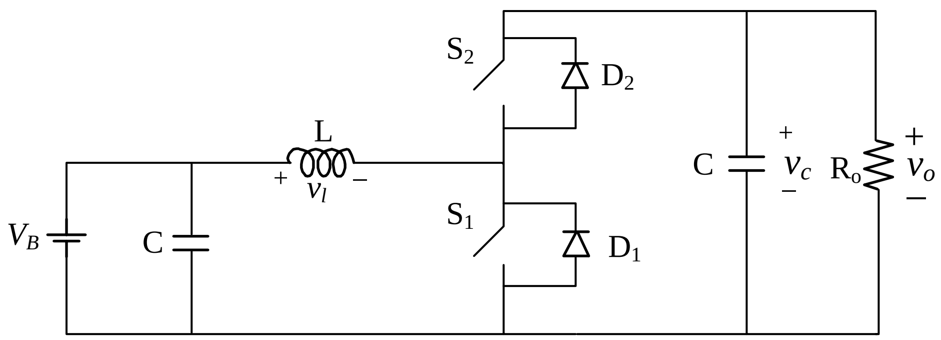

Figure 1: Bidirectional buck boost converter.

2.3 Closed Loop Diagram

2.4 Theory relevant to the project (in brief)

2.4.1 FCS-MPC control tecnique in Bidirectional Buck-Boost Converters

FCS MPC, or Finite Control Set Model Predictive Control, is an advanced control strategy used in various power electronics applications, including motor drives, active power filters, and voltage source inverters In FCS-MPC for bidirectional operation, the finite control set typically consists of various combinations of switch on/off states, enabling both buck and boost functionalities.

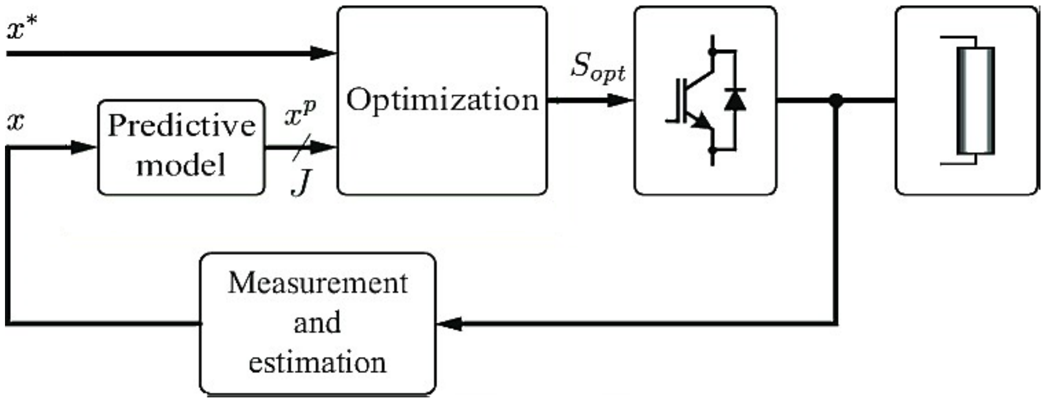

Figure 2: FCS-MPC CLOSED LOOP.

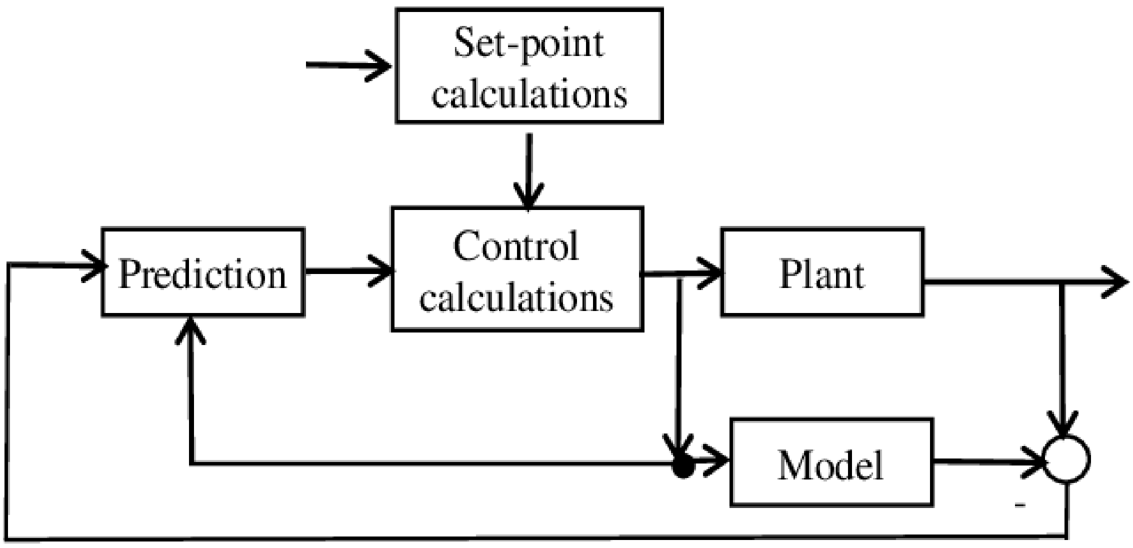

Figure 3: MPC CLOSED LOOP.

The controller chooses the combination that best achieves the desired power flow direction and magnitude FCS-MPC can seamlessly integrate current limiting constraints into its optimization process. This ensures safe operation while preventing overcurrent conditions that can damage the converter witching between charging and discharging modes can be challenging for conventional control methods. FCS-MPC facilitates smooth transitions by predicting the impact of each control option on mode change and selecting the smoothest path. Overall, FCS-MPC offers a powerful and adaptable control solution for bidirectional buck-boost converters, delivering precise power flow control, fast dynamic response, optimized performance, and robustness to nonlinearities.

- FCS MPC logics is capable of fast dynamics and versatility in handling multiple nonlinear control objectives.
- As inverters have a limited number of switching states they can be in at any given time. FCS MPC leverages this finite set of options for control.
- FCS MPC logic predicts how the system will respond to different switching states within the finite set and chooses the one that best achieves the desired outcome.

2.4.2 Bidirectional Buck Boost Converter

A bidirectional buck-boost converter is a type of DC-DC converter that can both step up (boost) and step down (buck) the voltage, and can also reverse the direction of power flow. It can also be used for battery charging and discharging. Its Applications includes:- Solar power systems Uninterruptible power supplies (UPS) Electric vehicle charging. The converter consists of four main components: Switches,Inductor,Capacitors, Controller. A "Bidirectional Buck/Boost DC-DC Converter" comes under a "Non-isolated converter" and This converter consists of two switches,inductor, and capacitors which are shown schematically in Figure 1.The converter has 2 operating modes Forward and Backward. In Forward mode, the electricity flows from the low voltage level such as the battery to the high voltage level side, and in this approach, the converter performs as a "Boost converter". At the time of regenerative braking, the electricity flows back to the low voltage level side to rejuvenate the battery and the converter performs as a "Buck converter".

2.4.3 Converter design calculation

The output voltage for the Bidirectional Buck/Boost converter is obtained by

$$V_o = \frac{D_b V_i}{1 - D_b} \tag{1}$$

$$V_o = \frac{D_{cd}}{1 - D_{cu}} V_i \tag{2}$$

Inductor ripple current can be calculated by using

$$\Delta I_l = \frac{V_i D c_d}{f_s L} \tag{3}$$

2.5 Simulation Setup

- Block Diagram

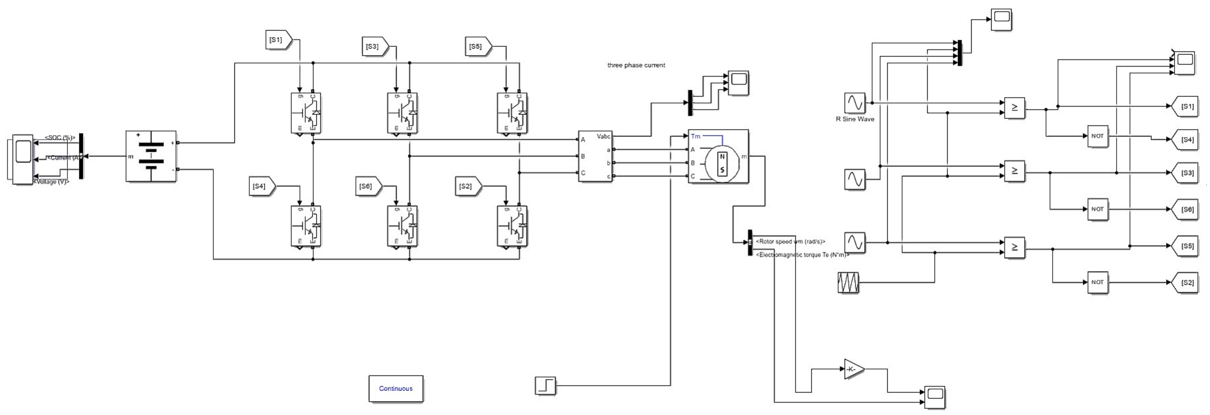

Figure 4: Matlab Block Diagram.

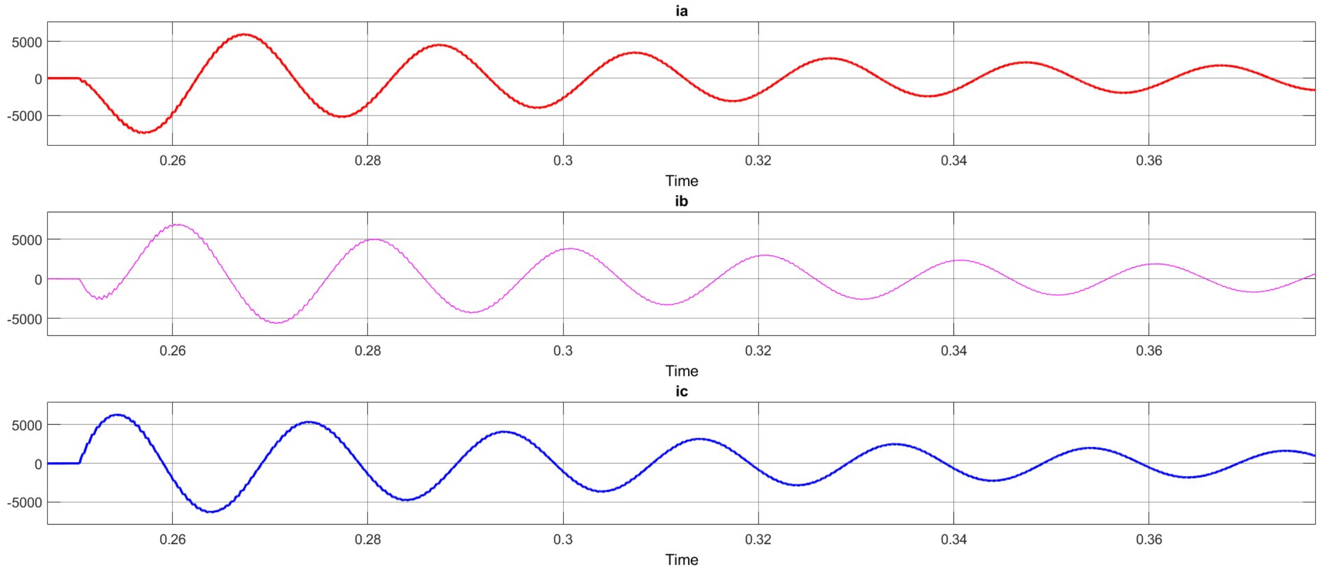

Figure 5: Output Currents.

2.6 Conclusion and future scope

- Optimizing grid integration of solar, wind, and other renewable energy sources by precisely managing power flow and storage
- Enabling faster, more efficient, and bi-directional charging for electric vehicles while ensuring battery health and safety.
- Employing bidirectional buck-boost converters for efficient and safe wireless power transfer for various applications like electric vehicle charging and biomedical implants

2.7 References

[1] A. Pirooz and R. Noroozian, “Model predictive control of classic bidirectional dc-dc converter for battery applications,” in 2016 7th Power Electronics. and Drive Sys. Tech. Conf. (PEDSTC), 2016, pp. 517–522.

[2] Caricchi, F. Crescimbini, G. Noia, D. Puolo, ”Experimental study of a bidirectional dc-dc converter for the dc link voltage control and regenerative braking in PM motor drives devoted to electrical vehicles,” Proceedings of the IEEE 9th Applied Power Electronics Conference and Erposition (XPEC'94). Orlando, Florida (USA), February 13-17,1994