ROBUST CONTROL DESIGN FOR BOOST CONVERTERS USING LMI TECHNIQUE

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ABSTRACT

In this paper, a robust control design for boost regulators based on the linear matrix inequalities (LMI) technique is investigated. Authors presented nonlinear terms as a convex polytope for designing a robust state-feedback controller in the vertex system using the LMIs technique. This work extends the regional pole placement problem to improve the transient behavior of the system based on polytope and LMIs properties. By introducing or manipulating some existing parameters, the controller can be designed in such a manner that varying values of these parameters indicate various regions where the closed-loop poles are located. MATLAB simulations are performed to validate this approach, and the findings are comparable to those of a PID controller.

Keyword: - *linear matrix inequalities (LMI),*

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1. INTRODUCTION

Most of the systems we encounter in real life are nonlinear in nature, necessitating the adoption of an efficient and effective Proportional Integral Derivative controller or one of its other combinations to fulfil the control target for trustworthy and feasible use of its output [1]. These are basic controllers that have been used in a variety of control systems as the main component. These are one of the most commonly used linear controllers. There are numerous methods for tuning the P, I, and D gains, including root locus, bode plots, Ziegler-Nichols methods, and so on. Unfortunately, a single tuning method rarely addresses a wide range of issues such as load disturbances, measurement noise, and model accuracy [2]. The great majority of the designs in its vicinity are based on linearized models. When developing controllers for such systems, higher-order dynamics are typically ignored [3].

As a result, the performance of the closed-loop system may fluctuate dramatically during operation, which may be unforgivable at times, or, to put it another way, the closed-loop system may be unable to provide the precise anticipated output, no matter how close it is. As a result, when designing the controller, such uncertainties must be taken into account. Controllers must be developed in such a way that they can accomplish good performance even under uncertain conditions to fulfil the expectations of today's control objectives. Throughout the uncertainty domain, a good robust controller should keep the closed-loop system stable and operate well. We present a prospective framework that uses a polytopic model to transcend these undesired nonlinear changes, allowing the development of a linear controller that maintains optimum system performance considering the real system model. The nonlinear characteristics were treated as structural uncertainty, which can be expressed more simply with a polytopic model. Polytopes are con vex representations of constrained parameter changes in uncertain matrices that govern the uncertain nonlinear fluctuations of the system [4]. In the controller design, the pole placement strategy aims to optimize closed-loop dynamics by ensuring the maximum natural frequency (ω_d), the minimum damping rate, and the minimum decay rate (α) [5]. This adjusts the delay, maximum shock and adjustment time individually. Since the transient response of a linear system is dictated by the poles, specific limits can be created by limiting closed-loop poles sufficiently to keep them in a particular region, resulting in a satisfactory transient response [6].

Polytopic systems are polyhedron-related convex polyhedron systems with parametric uncertainty [7]. Such systems are well-studied type of systems that represent parametric uncertainty, allowing for a more robust control design. Because the challenge of robust control design for such systems is non-convex, numerical techniques (possibly based on LMI) must be utilized to find a solution. LMIs can be used to track these representations statistically [8].

PID and other linear controllers are straightforward to implement. Robust linear control systems, unlike nonlinear and conventional control systems, account for parametric uncertainty. Effective uncertainty management in power converters is crucial because some regulator properties, such as storage components or load, are time-dependent or partially unknown. As a result, we'll have to deal with these uncertainties in a different way [9]. Some of the robust procedures successfully adapted to power electronics are H_∞ [10], μ-synthesis [11], quantitative feedback theory (QFT) [12], and approaches based on linear matrix inequalities (LMI) [13]. To compare such techniques, a few of their aspects must be highlighted: H_∞ and μ-synthesis approaches [8], [14] and [15] need the designer to randomly select weighting functions to define acceptable performances and approximate transient features. In contrast, LMI-based control does not require weighting functions and can manage abrupt demands with pole positioning constraints. Furthermore, the QFT technique [8] necessitates human optimization of the controller expression, whereas LMI control offers automatic optimization of the controller parameters.

2. BOOST CONVERTER MODELLING

Using linear control methods, the circuit switching technique is employed to tackle the problem of stabilizing a boost converter in small-signal settings. Following the construction of a small-signal circuit model for the boost regulator with state-feedback, the requirements for the circuit's stability are studied [11].

Following that, linear analysis is performed to develop the needed dynamics and robust behavior of the boost converter. Given the equilibrium point, the linear analysis assumes that all that is needed is a state feedback gain matrix [11]. The feedback loop's basic operation is to compare the output variable with a reference input to create an error signal, which is then appropriately filtered and amplified to give a continuous control signal. This signal is altered via PWM, which sets the switch *duty cycle* [11].

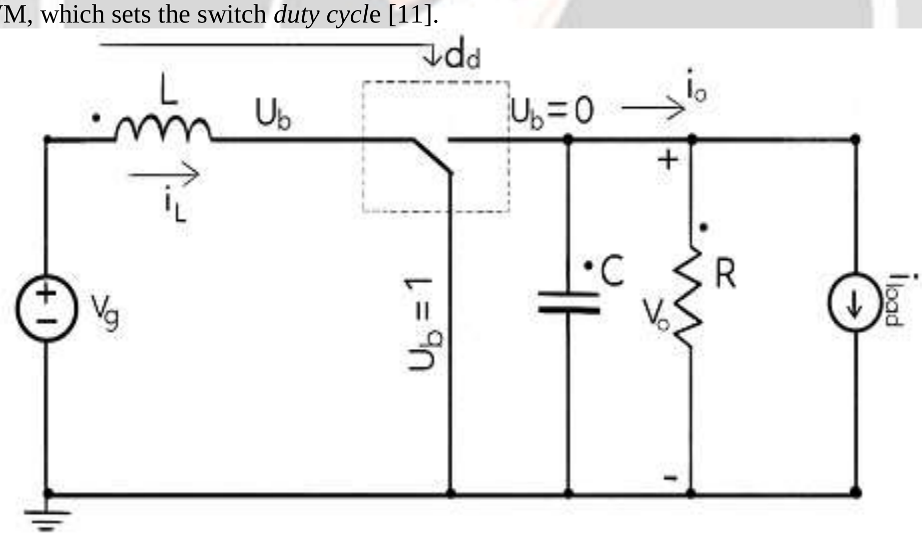

Fig -1 Boost converter circuit diagram

3. SIMULATION RESULTS

To demonstrate the robustness of the proposed controller, we simulated the transient behavior under nominal and off-nominal situations. Simulation diagram of boost converter controller using LMI and PID are depicted in figure 2 and figure 3 respectively.

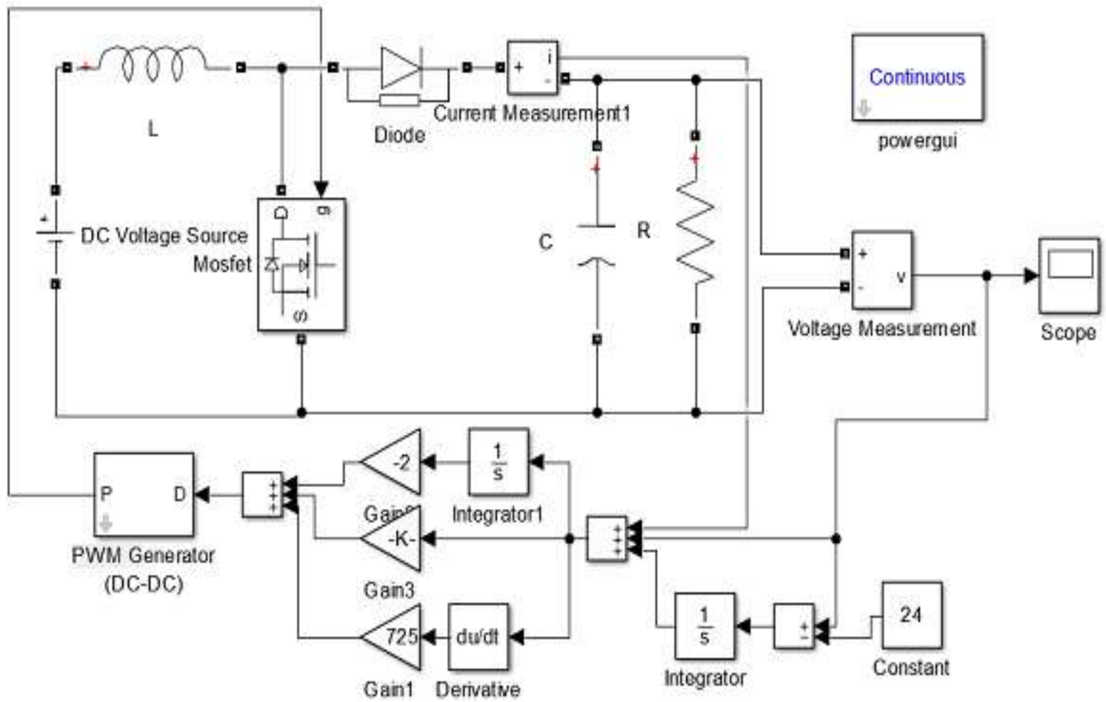

Fig -2 Boost converter with LMI control simulation diagram

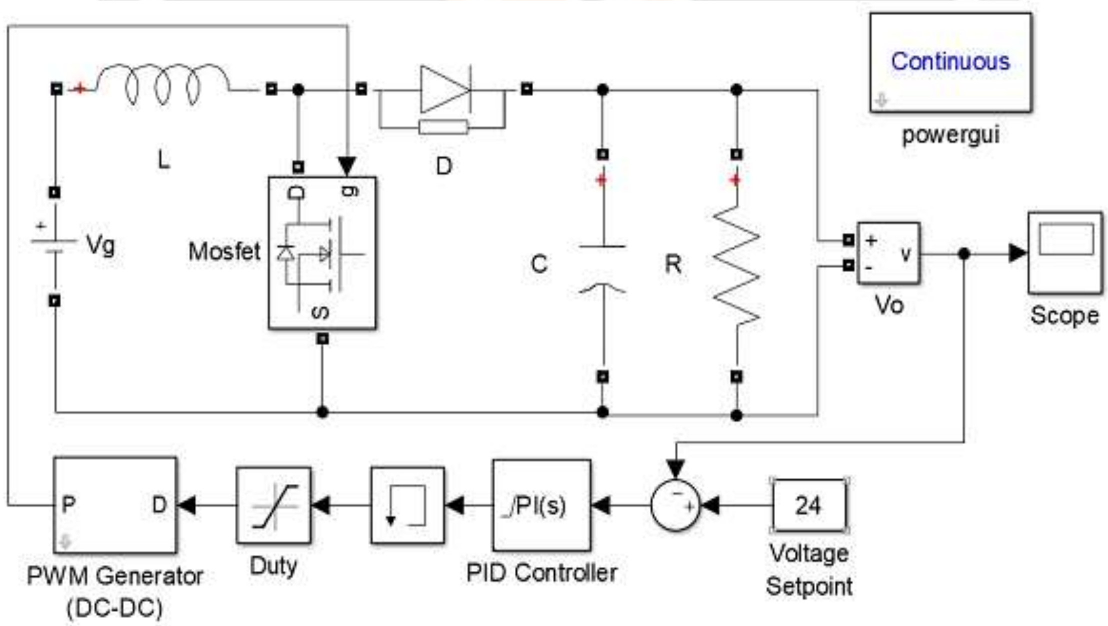

Fig -3 Boost converter with PID control simulation diagram

Fig 4 illustrates the output voltages *(*v_o. for PID control circuit, v_{ol} for LMI control circuit) for the converter with nominal parameters. It is worth noting that the output voltage response has a time constant of around 10 ms, which equates to a decay rate of 400, which is more than the minimum specified decay rate ($\alpha = 130$). Furthermore, the output voltage has a slight overshoot, which is consistent with the damping ratio limitation [11].

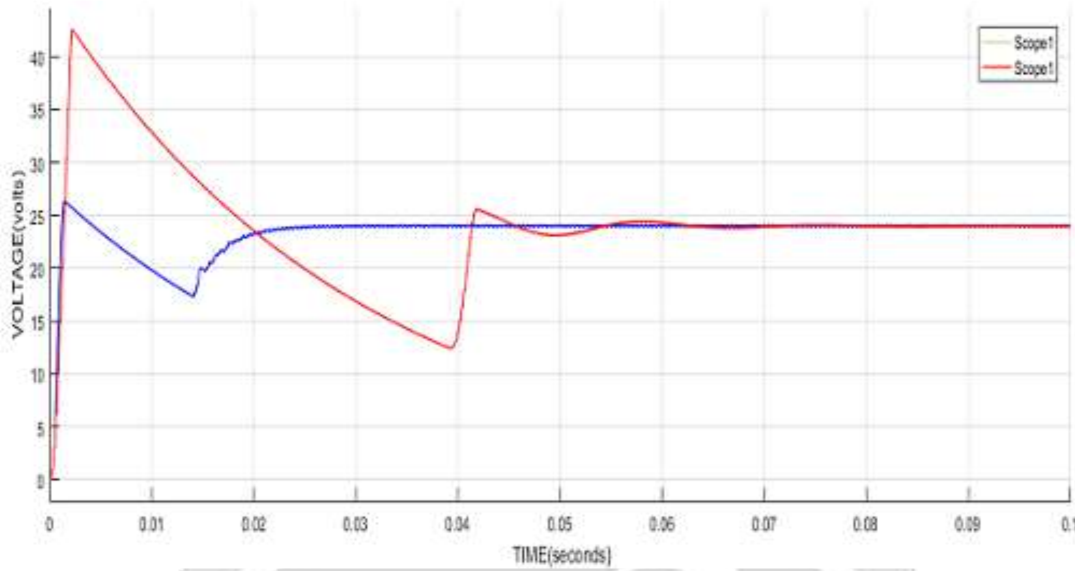

Fig -4 MATLAB simulated response with the nominal load R = 50 Ω under *nominal duty cycle* D_d = 0.5

System response for the proposed controller maintains an output voltage over shoot. Although this overshoot remains within the specified damping ratio restriction. Furthermore, the decay rate is about 200, which is less than the nominal case but larger than the stated a. Fig 5 depicts the same simulations as Fig 3 but with a different non-nominal load of *R*= 10 V. According to the simulations, the LMI controller fulfils the damping ratio criterion and has a lower decay rate than the necessary α.

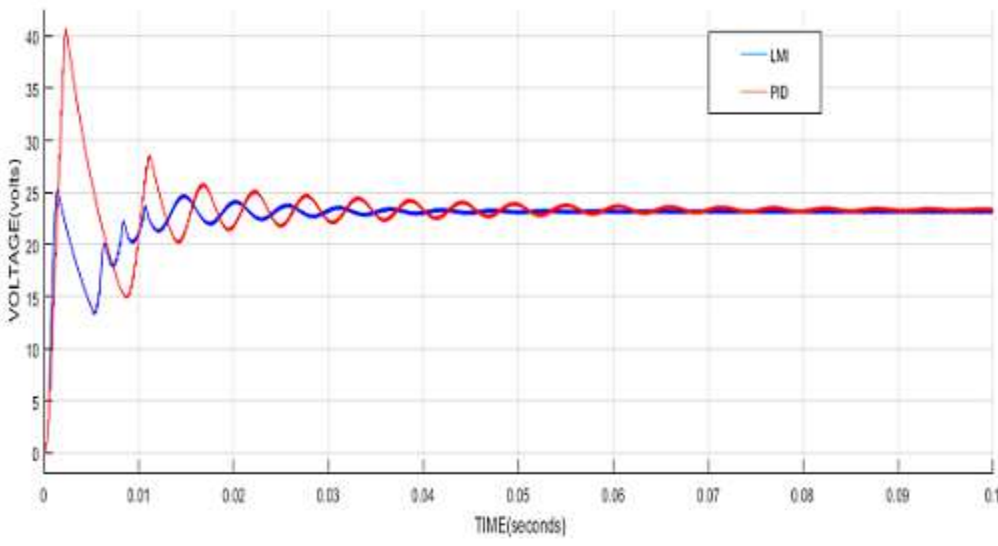

Fig -5 MATLAB simulated response with the nominal load R = 10Ω under nominal duty cycle D_d = 0.5.

4. CONCLUSIONS

The boost converter was designed using the LMI design approach, and the results were assessed using numerical simulations and a standard PID controller. For non-minimum phase converters, the state-feedback LMI technique is reliable synthesis method. Despite the uncertainty model's conservatism, the suggested technique can account for transient and steady-state performance, and the final design performs well in this regard. The state feedback controller may be automatically synthesized using this technique, in a contrast to other robust control systems that need the controller to be synthesised manually or with CAD tools.

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