Robust Stability Analysis of Average Model of STATCOM using an Approach based on Semidefinite Programming

A. Ghezel-Soflu[1]and M. Moradpour[2]

[1] *Department of Mathematics, K.N. Toosi University of Technology, P.O. Box 16315-1618, Tehran, IRAN,ali.nov7@gmail.com*

[2] *Electrical Engineering Department, K.N. Toosi University of Technology, Tehran, IRAN,* milad_7_64@yahoo.com

Abstract. In this paper, we consider state space average equations which are called STATCOM [1]. STATCOM is one of the FACTS devices in the electrical energy distributions context [2]. The average equation leads the system to an exact mathematical model and provides a better performance and tracking to the system. Using an approach based on semidefinite programming, we analyze the Lyapunov [4] stability of the time-varying linear system that arises in STATCOM. We also discuss about the robustness of the system and provide some numerical results using SeDuMi to show the efficiency and effectiveness of the proposed approach.

Keywords: Semidefinite programming; Robust optimization; STATCOM

I.INTRODUCTION

The use of control methods in STATCOM offers a better performance along with making possible tracking of the desirable references more efficiently. Usually, a mathematical model is needed for a system in order to achieve a special purpose using a routine control method arrangement. Nowadays, many efforts have been done to achieve simpler, more objective as well as more precise mathematical models. Standard state space average model (SSSAM) is a well-known technique for modeling STATCOM which considers the switching behaviors of power electronic devices []. Using this model, a wider range of state space controllers such as optimal control, adaptive control, robust control, and etc, can be applied to the STATCOM.

In this paper, we propose a robust optimization scheme for analyzing the SSSAM of STATCOM using Semidefinite Programming (SDP) problems. We

note that the SDP problems are a natural language to pose and to process numerous problems related to the stability and robustness arising in engineering and mathematical programming. Using Lyapunov stability, we introduce new robust optimal feedbacks that are satisfied with state variable stabilization. In fact, we deal with the uncertainties which arise in the input data of the affine equation in the mathematical model of STATCOM.
The paper is organized as follows: In Section 2, we apply the methodology procedure to the STATCOM. Section 3 presents SDP relaxation for the dynamic equation. In Section 4, some numerical results are given to show the efficiency and effectiveness of the proposed method.

II.Methodology procedure

A control algorithm for time-varying system should be used to design a closed-loop system like Fig. 1.

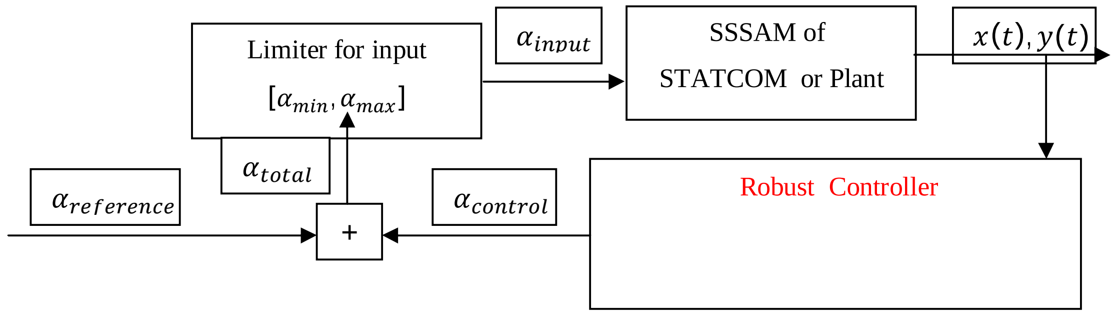

Fig. 1

$$\dot{x}(t) = A(t)x(t) + B(t)u(t) \tag{1}$$

where $A\,(t)_i \in M^{3\times3}$, $B\,(t)_i \in M^{3\times1}$. We can analyze the Lyapunov stability of this system using SDP approach. In fact, our aim is to design a robust controller to the model of STATCOM. It is shown that the Lyapunov stability of this system can be obtained by the following SDP problem:

$$\begin{aligned} &\min\ \beta \\ &\text{s.t. } Y \succ I \qquad\qquad (*) \\ &H^T B^T + Y A^T + B H + A Y \preccurlyeq \beta I \qquad \forall \boldsymbol{i} = \mathbf{1}, \dots, \boldsymbol{N} \end{aligned}$$

Where H and Y are defined as $Y = L^{-1}, H = KL^{-1}$ that L is a semidefinite positive matrix according to Lyapunov quadratic function and K is ours closed loop feedback. System (1) is stable if and only if the optimal value of this SDP problem with design variables β, Y, H, is negative. We can solve this problem using SeDuMi software [5].

III. Numerical Results

The Simulation results of closed loop system are provided in Figure 2. These figures show that states are sinusoidal with constant amplitude. Both $i_a(t)$and $i_b(t)$ have identical frequencies to that of the grid network, and the DC-link $V_c(t)$ has a dominant oscillations twice the frequency of the network. So, these state variables are stable.

It is necessary to have α_0 when simulating Fig. 2. Also, different α_0 can be selected from $\alpha \in [-1.5,1.5]$ as below [5]:

$$\alpha_0 \in \{-1.5, -1.0, 0.0, 1.0, 1.5\} \qquad (**)$$

Then, for every $\alpha_{input} \in [-1.5,1.5]$, the closest α_0 is selected from (**). In this paper, the simulations of Fig. 2 is carried out for $\alpha_{input} = -0.5$ and $\alpha_{output} = -0.5$.

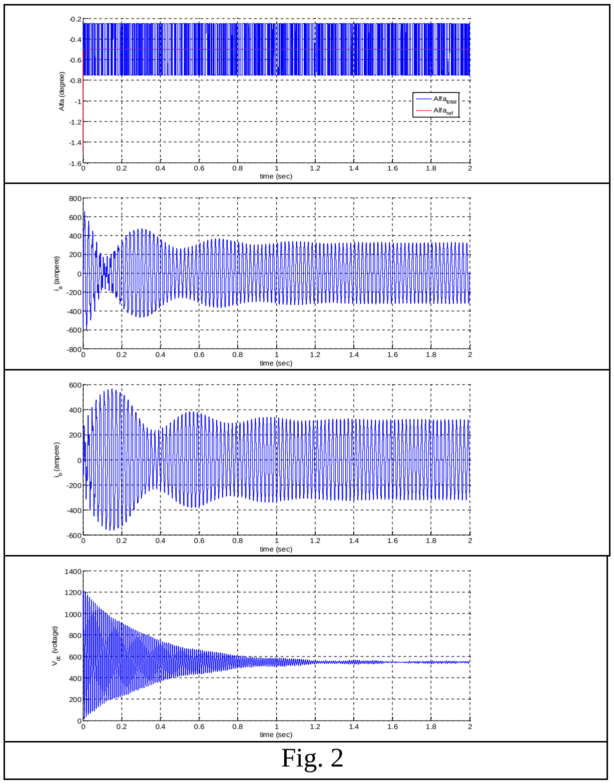

Fig. 2

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