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Dynamic matrix control and generalized predictive control, comparison study with IMC-PID

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ABSTRACT

Two of control techniques of the Model Predictive Control (MPC) methodology, which are Dynamic Matrix Control (DMC) and Generalized Predictive Control (GPC), with IMC-PID are disputed in this paper. The main characteristics of these important control techniques, widely used in industry, are presented. The optimum solution of the predicted control inputs and outputs are obtained by minimizing a cost function that contains the squared errors between the reference trajectory and predictions output on the prediction horizon. These controllers are applied on a Process Control Module (PCM), a system with pure time delay, and tested in the light of disturbance rejection and tracking performance for the constant and variable trajectory.

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Introduction

Model Predictive Control (MPC) is an advanced control technique [1]. Besides to its ability to predict the behavior of systems, MPC technique gives solution for problems of many types of complex systems such as open-loop unstable systems, non-minimum phase systems, the large delay systems, etc. For this reason, the MPC technique is adopted for thousand industrial applications especially in refining and petrochemical sectors [2]. Nevertheless, this technique was not implemented in the industry only in 1973 [3]. Many approaches belong to MPC, from this year up to now are appeared such as Dynamic Matrix Control (DMC) that developed by Cutler et al., in 1980 [4], Quadratic Dynamic Matrix Control (QDMC) in 1986 developed by Garcia et al. [5]. Generalized Predictive Control (GPC) that developed by Clarke et al., in 1987 [6], Predictive Functional Control (PFC) developed by Richalet and ADERSA [7,8] in 1993 and the newest one was the Global predictive control (Glob-PC) appeared in 2000 and developed by Desbiens et al. [9]. The differences between those algorithms reside in the cost function and representative model.

Some comparative studies are done between these techniques. The Model Predictive Control (MPC) is tested for hydrogen production system; The Linear MPC (LMPC) and the Predictive Functional Control (PFC) are applied on this system and allowed to obtain the best performances compared to the PI regulator [10]. The PFC technique is estimated as a good choice regarded to its simpler design associated with another predictive approach [11]; however, it has its drawbacks in some cases as Multiple Input Multiple Output systems (MIMO),

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some situations of constraints, in analyzing and modeling … etc. [12].

LMPC has also applied on ethanol steam reformer (ESR) for minimization and setpoint tracking, it gives good results with this linear ESR that proceed from nonlinear ESR model [13]. A cell generation system is tested by MPC that proves its feasible and effectiveness compared to the PID controller where a neural network algorithm is used to reduce its computational time in a simulation study [14].

Output tracking for spark ignition engines is examined by MPC and PI with Smith predictor in a comparative study in the case of delay in the term of performance [15].

For the DMC technique is verified on a reformer of steam gas and its performances are improved compared to the classical controller [16]. In the [17], the GPC technique is solved with linear equations in the case of inactive constraints, a problem of a convex optimization is resolved to find the gain of output feedback after satisfying the coefficient matrices rank conditions using a square system. This technique is modified and applied to a second-order system with delay time to examine performance beside stability in case of non-minimum phase and minimum phase zeros [18].

In this paper, the study is focused on two important algorithms of MPC, which are Dynamic Matrix Control (DMC) and Generalized Predictive Control (GPC). These tow controllers are widely used in industry compared to other advanced controllers and give a solution to the most complex dynamic systems. Dynamic Matrix Control (DMC) use step response representation to predict the input and output. It has the ability to control high dimension multivariable systems and handling constraints, which represent its industrial success [24]. The GPC is a robust algorithm. It has the ability to control a large wide of systems with little prior knowledge of either a simple or a complex system. Both controllers are used to control a Process Control Module (PCM). We chose this application simulated in the paper, represented by first-order model with delay time because it is considered a typical problem often encountered in the process industry especially for the industrial units that can be designated as interactive SISO systems. The tracking performance is examined in the presence of disturbance and for constant and variable trajectory. A compared study with a classical controller, which is Internal Model Control IMC-PID, is introduced, however, other comparative studies between MPC and PID controllers can be found, among others, [11,18–22]. The classical controller parameters based on Internal Model Control (IMC) showed closed loop performance and robustness, for SISO systems with delay time, by the use of these rules [23]. The simulation results illustrate that the used controllers are very effective. They could achieve the objectives with advantages to predictive controllers in the robustness and tracking performance.

This paper is devoted for three controllers and its organization is as follows: Section Dynamic Matrix Control Technique shows the dynamic matrix control formulation and its synthesis. Generalized predictive control technique is described in Section Generalized Predictive Control 'GPC' technique. Section Simulation results illustrate the performances of these techniques applying on a process control modules. Finally, the conclusion of the paper is summarized in Section Discussion of the simulation results.

Dynamic matrix control technique

Dynamic Matrix Control (DMC) use step response representation to predict the input and output. The ability to control high dimension multivariable systems and handling constraints represent its industrial success [24].

This formulation used below permit a more intuitive understanding of how predictive control operating. Nevertheless, similar developments can be conducted with impulse response model where the transfer function leading respectively to the Model Algorithmic Control 'MAC' and generalized predictive control 'GPC'.

Output prediction

The step response (Fig. 1) of the system can be described by the Eq. (1).

$$y(t) = \sum_{i=1}^{+\infty} g_i \Delta u(t-i) \tag{1}$$

with y(t) is the model output, the g_i is the coefficients of the step response and Δu is the increment of the command ($t \in Z$: discrete).

So, the prediction of the output at $(t+k)$ is given by:

$$\hat{y}(t+k/t) = \sum_{i=1}^{+\infty} g_i \Delta u(t+k-i) + \hat{\eta}(t+k/t) \tag{2}$$

where $\hat{\eta}(t+k/t)$ is the predicted disturbance in the time $t+k$, (Fig. 2).

This equation can be rewritten as

$$\hat{y}(t+k/t) = \sum_{i=1}^{k} g_i \Delta u(t+k-i) + \sum_{i=k+1}^{+\infty} g_i \Delta u(t+k-i) + \hat{\eta}(t+k/t) \tag{3}$$

It is supposed that disturbance is constant along the prediction and it equals the difference between the measured output y_m (t) and the model output y (t). It is given as:

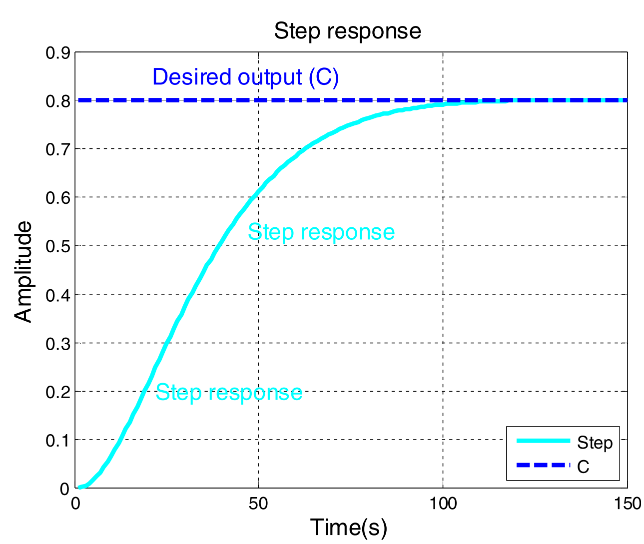

Fig. 1 – Step response.

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