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Implementation of Model Predictive Control in Real Time Systems

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Abstract— Model Predictive Control (MPC) has many advantages which cannot be realized because of its complicated nature and restricted application. In this paper closed loop response of MPC is compared with unconstrained optimal controller and the results are plotted. MPC operation is shown in function block with simple assigning process with complete setup being automated. In this paper, graphical representation of MPC inputs and outputs, visualization with editing, simulation and verification of model are provided. The results show that using MPC is very useful for real time systems as the throughput is increased.

Keywords— MPC; automation; implementation.

I. Introduction

Dynamic model is used for predicting the future response of the controlled plant. It deals with discrete-time linear systems with state-space depiction.

$$x(k + 1) = Ax(k) + Bu(k)$$

with x(k) and u(k) as model state and input vectors at k^{th} sampling instant. With predicted input sequence, its corresponding state prediction sequence is generated by simulating the model forward over the prediction.

MPC was designed by DMC [1] and IDCOM [2] in 1970s and is well accepted by industry. Process control problems are analyzed in time domain. It is difficult to effectively control multiple-input multiple-output processes with constraints and instabilities, processes with complex dynamics, PID approaches like feed forward control, decoupling, override control, and so on. Since MPC is ideally suited to such processes, it appears that there is considerable interest in applying it to process control. There are both hypothetical and practical complications related to its traditionally complex nature and huge costs.

MPC is a multiple-input/multiple-output control strategy with effects of varying the number of process inputs on each of a number of process outputs. The model of the process is created by measuring the response. The process model is inverted mathematically and used as a multiple-input/multiple-output controller to control the process outputs based on changes made to the process inputs. Figure 1 depicts the structure for implementation of this strategy. A model can be created for predicting the upcoming output of plant using the present and past. The optimizer calculates these actions taking into account the cost function as well as the constraints. The main ideas appearing in a predictive controller are discussed in [3]:

Figure 1 depicts the explicit use of model to predict process output at future time instants. It deals with

- Design of control sequence for minimizing the objective function
- Receding strategy in which the horizon is displaced towards future with the application of control signal

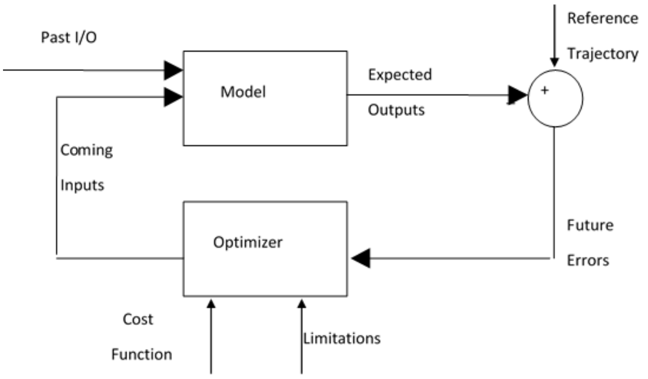

Fig.1. MPC process.

Model predictive control presents distinct advantages over other control methods. It can be used for variety of processes, from simple dynamics to complex ones with long delay times. By design, it handles the multivariable case, including compensation for measurable disturbances in a feed-forward control fashion, as well as a systematic treatment of constraints. It intrinsically compensates for dead times and is also very useful when future references are known. The resulting controller is implemented easily as linear control law. Added to that is the intuitive approach and ease of tuning, making it extremely attractive to plant operators. Although these features have led to an increased interest with a number of reported applications to control problems, MPC has not yet reached in industry the popularity that its potential suggests. One of the reasons is that its implementation requires mathematical complexities (for example, the derivation of the control law is more complex than that for classical PID) which are not a problem for the research community but represent a drawback for control engineers in practice.

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II. Customary MPC Environment

Initially, to create an MPC for a process, an expert must be hired. He will visit the plant and witness the plant operation closely for a short period. The expert will choose suitable process inputs and outputs values for MPC after closely working with plant operators and measuring the consequence of inputs on selected process outputs.

Using the input-output data collected, it is fed to off-line system which is in expert's control for analysis. This system helps in creating a model of the whole process. Then it is fed to the real process control system and tuned by process engineers. After it is made sure that the installed MPC system works properly, controller's integration must be taken care so that operator use it.

Because of the complexity of the system, integration problem will be encountered and the entire process will be expensive. The process may also take any year for implementation in case of larger plants. Maintenance of the plant may also require experts support. Regular scaling and up gradation may require the repetition of entire process for new MPC. The customary and proposed approach of implementation is shown in figure 2.

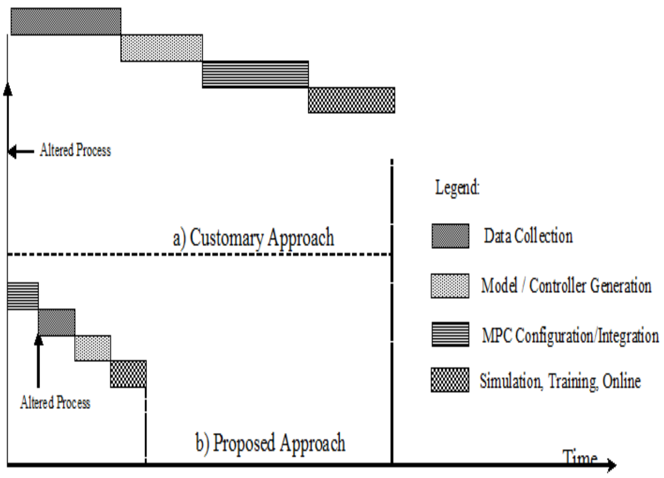

Fig. 2. Customary and proposed MPC approach implementation.

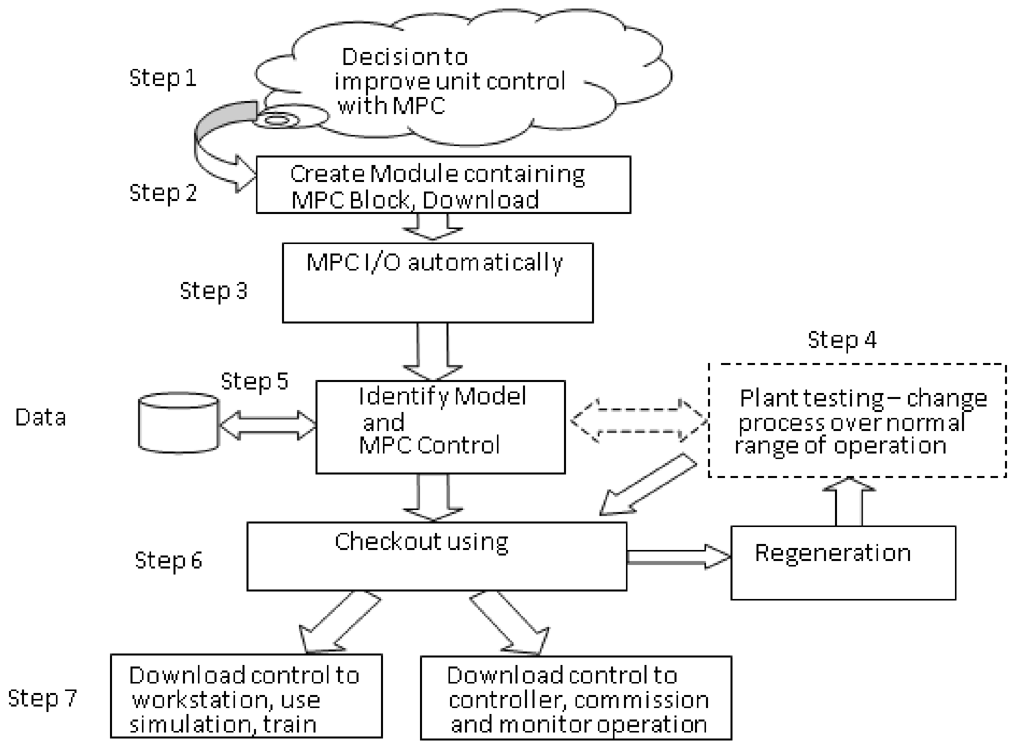

Fig. 3. Steps in MPC implementation.

III. Proposed Approach

In this paper, an approach that streamlines the whole life cycle of MPC is designed. In this method automation of data collection, control generation and commissioning process is done without affecting the technology. This makes it extremely easy and intuitive for the plant engineer to relate his process knowledge in MPC implementation with little understanding of its mathematical complexities. The whole process of producing the controller is implanted in application whereas in old approaches layering it on top of the control system is followed. The process followed in MPC development and maintenance is illustrated in figure 3.

The control strategy that is implemented uses function blocks [4], in which every block acts as subroutine for complete system. Function blocks can perform either the input/control/output function. Control routines can take many forms like hardware/software/firmware. Control modules can be designed with programming language also. The approach has many advantage of ease of use and flexibility.

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IV. EXPERIMENTAL RESULTS

After designing the MPC controller, the closed loop response with unconstrained optimal controller and designed MPC controller is compared. The response for unconstrained optimal controller is shown in figure 4. Plot tightened input constraints is shown in figure 5 and closed loop response with MPD is shown in figure 6. Figure 7 shows the response of closed loop system with MPC.

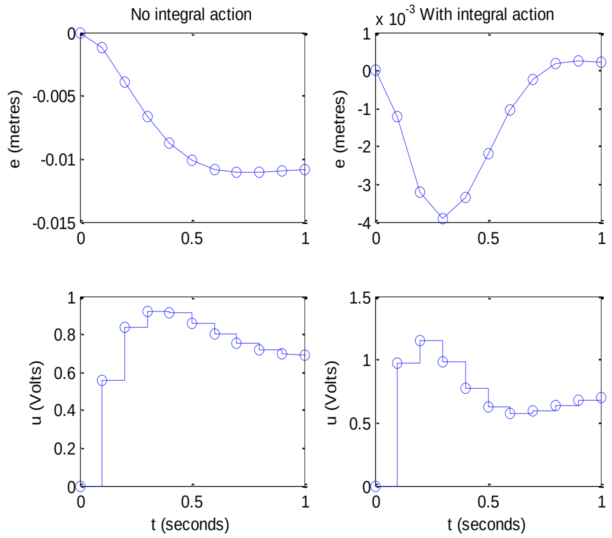

Fig. 4. Closed loop response with unconstrained optimal controller.

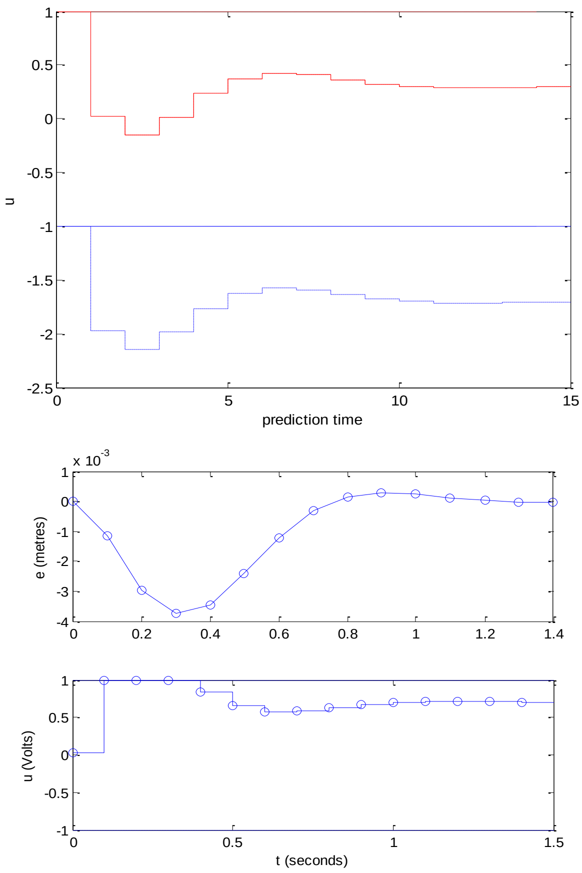

Fig. 5. Plot tightened input constraints.

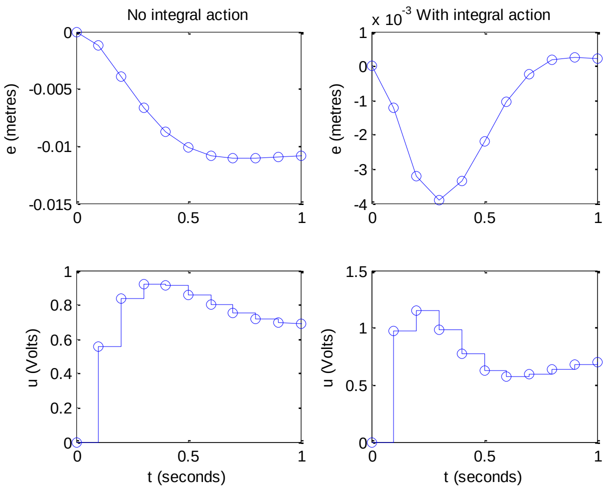

Fig. 6. Closed loop response with MPC.

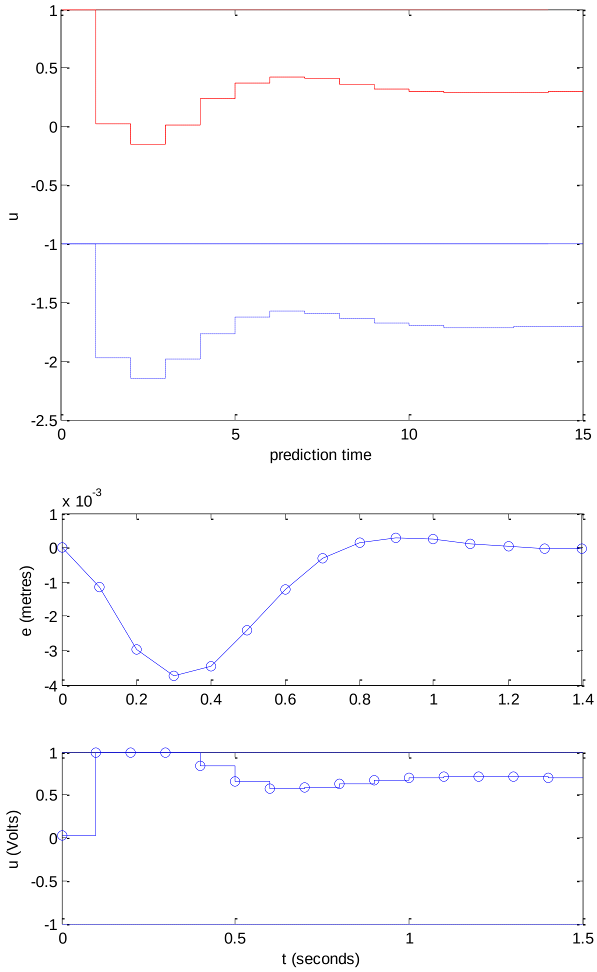

Fig. 7. Closed loop system with MPC.

V. CONCLUSION

A new method of development and implementation of model predictive controllers has been presented. By embedding the MPC function block in control system with

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controller automation, MPC techniques is implemented for various plant process. A GUI based application maintains the underlying MPC technology, while minimizing the engineering effort and making the implementation process extremely easy and intuitive. Since the functionality is implemented in the same format as other control blocks within the control system, integration and operation are fairly straightforward, thereby minimizing downtime. A simulation environment is provided as part of the application. It is intended that MPC be used extensively to provide better control than complex PID strategies. Using an example we demonstrate how the presented novel approach can be used towards realizing this objective. In the future we would be addressing the adaptive control case in the same paradigm.

REFERENCES

[1] C. R. Cutler and B. L. Ramaker, "Dynamic matrix control – a computer control algorithm," AIChE Annual Meeting, Houston, TX, 1979.

[2] J. Richalet, A. Rault, J. L. Testud, and J. Papon, "Algorithmic control of industrial processes," *Proceedings of the 4th IFAC Symposium on Identification and System Parameter Estimation*, pp. 1119-1167, 1976.

[3] E. F. Camacho and C. Bordons, *Model Predictive Control In The Process Industry*, Springer-Verlag, London, Great Britain, 1995.

[4] T. Blevins, W. Wojsznis, V. Tzovla, and D. Thiele, "Integrated advanced control blocks in process control systems," US Patent Application, Fisher File No: 59-11211.

[5] D. Thiele, "Benefits and challenges of implementing model predictive control as a function block," *Proceedings of ISA Expo/2000*, New Orleans, LA, 2000.

[6] W. K. Wojsznis, T. L. Blevins, and M. Nixon, "Easy robust optimal predictive controller," *Proceedings of ISA Expo/2000*, New Orleans, LA, 2000.

Betty Elezebeth Samuel and Latha Parthiban, "Implementation of model predictive control in real time systems," *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 1, pp. 123-126, 2016.