MULTICONTROLLER: AN OBJECT PROGRAMMING APPROACH TO INTRODUCE ADVANCED CONTROL ALGORITHMS FOR THE GCS LARGE SCALE PROJECT

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Abstract

The GCS (Gas Control System) project team at CERN uses a Model Driven Approach with a Framework - UNICOS (UNified Industrial COntrol System) - based on PLC (Programming Language Controller) and SCADA (Supervisory Control And Data Acquisition) technologies. The first' UNICOS versions were able to provide a PID (Proportional Integrative Derivative) controller whereas the Gas Systems required more advanced control strategies. The MultiController is a new UNICOS object which provides the following advanced control algorithms: Smith Predictor, PFC (Predictive Function Control), RST* and GPC (Global Predictive Control). Its design is based on a monolithic entity with a global structure definition which is able to capture the desired set of parameters of any specific control algorithm supported by the object. The SCADA system – PVSS - supervises the MultiController operation. The PVSS interface provides users with supervision faceplate, in particular it links any MultiController with recipes: the GCS experts are able to capture sets of relevant advanced control algorithm parameters to reuse them later. Starting by exposing the MultiController object design and implementation for a PVSS and Schneider PLC solution, this paper finishes by highlighting the benefits of the MultiController with the GCS applications.

OBJECT DESIGN

The MultiController object has been designed for the Gas Control System Project (GCS) to fulfil a real need of advanced control loop strategies [1]. Moreover, the object design is the result of requests from multiple users and previous experience with existing PID controllers at CERN. The MultiController is an object implementing a solution for PLCs and SCADA systems and offering many advantages in terms of usability, functionality and extensibility *(Figure 1)*.

The MultiController has a single interface for all regulation algorithms. The object structure is implemented with a set of parameters used for all possible algorithms. Parameters are treated according to the selected regulation method. A given parameter can be used by several regulation methods. The design allows the addition of new control loop algorithms without changing the object interface.

**RST is not an acronym*

The MultiController has two separate behaviours: "Regulation" and "Positioning". In "Regulation" the object works with a control loop algorithm whereas in "Positioning" the object works without any control algorithm and puts a pre-determined value on the output of the MultiController.

The parameters can be modified in any of the three modes defined by UNICOS (Manual, Manual Force and Automatic). Moreover the MultiController has been designed to offer a recipe mechanism allowing the process expert to keep and reuse pertinent sets of tuning parameters.

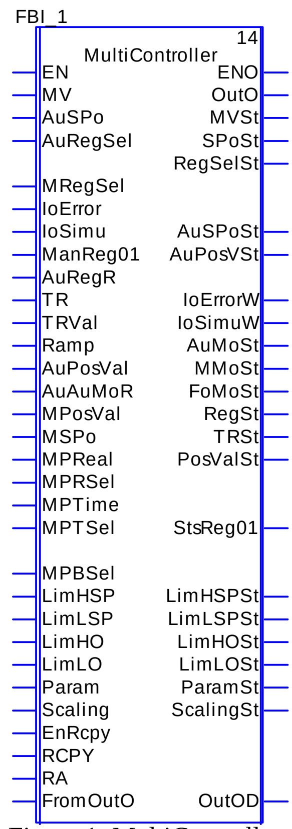


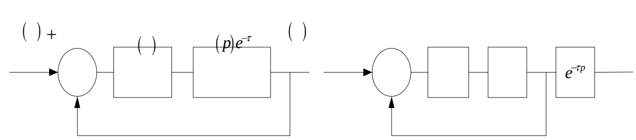
Figure 1: MultiController in PLC.

ADVANCED CONTROL ALGORITHMS

The MultiController object support the following advanced control algorithms: Smith Predictor, PFC, and GPC (PID algorithm is also integrated but is not considered as an advanced feature of the object).

Smith Predictor Principles

The Smith Predictor has been proposed [2] to compensate for long dead-times. It consists of finding a fictive structure *(figure 2)* so that the delay is hidden from the closed loop system.



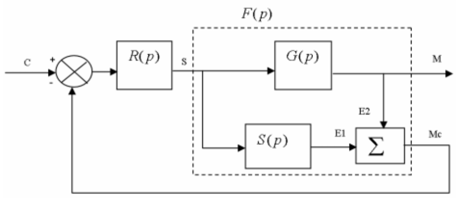


Figure 2: Smith Predictor principle.

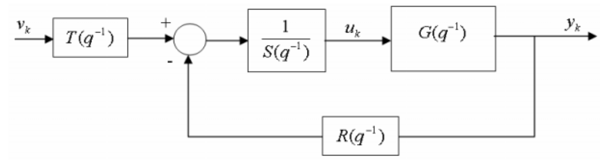


Figure 4: The RST controller.

Predictive Function Control Principles

The Predictive Function Control (PFC) principles have been introduced in the early 1980's [3, 4]. It applies the same predictive strategy developed for the General Predictive Control (GPC) but uses different concepts to achieve the control signal. Giving the Setpoint on a receding horizon, the predicted process output will reach the future Setpoint following a reference trajectory *(figure 3)*. Additionally the PFC uses a model to build the control signal.

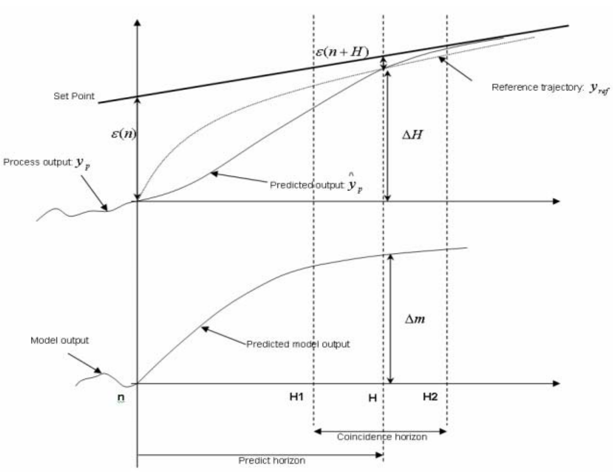


Figure 3: Predictive Function Control principles.

Generalized Predictive Control Principles

The Generalized Predictive Control (GPC) proposed by Clarke *et al.* [5, 6] is a Model Based Control (MBC) strategy. The principle of GPC is to calculate a future sequence of control signals in such a way that it minimizes a cost function over a prediction horizon.

RST Controller Principle

The RST* controller representation is extremely useful for PLC implementation due to its simple structure. The polynomial approach in q overcomes the usual inconvenience introduced by the sampling time *(figure 4)*.

The RST controller is often used to calculate robust closed loop response by pole placement. The structured control signal introduced by the RST representation is done so that any controllers can be represented through the RST formalized schema.

The RST controller is driven by the following equation:

$$S(q^{-1}).u_k = T(q^{-1}).v_k - R(q^{-1}).y_k \quad (1)$$

MULTICONTROLLER ADVANCED CONTROL IMPLEMENTATION IN PLC

The PLC programming concept is a cyclic execution process. The diversity of process control applications has also led to the introduction of the multi program cyclic principle for PLCs by means of four standard languages available through the IEC61131-3 norm [7]:

- the Instruction List (IL)
- the Structured Text (ST)
- the Ladder Diagram (LD)
- the Functional Block Diagram (FBD)

According to the IEC61131-3 norm the MultiController written in ST can be called by a routine written in any of the four languages. The MultiController advanced control algorithms are set up by using the cyclic execution as a sampling time reference. The algorithms are then developed with emphasis on the sampling aspect commonly defined in the automation processes.

HUMAN MACHINE INTERFACE

The MultiController HMI representation uses the SCADA system PVSS. It is composed of synoptics, trend views, navigation buttons, etc. The object programming approach of the MultiController through a PVSS schema is a single monolithic representation by means of a custom faceplate, a unique set of trends and a unique recipe mechanism. It allows a global control of the regulation loop via a centralized object representation in the HMI with different views *(figure 5)*.

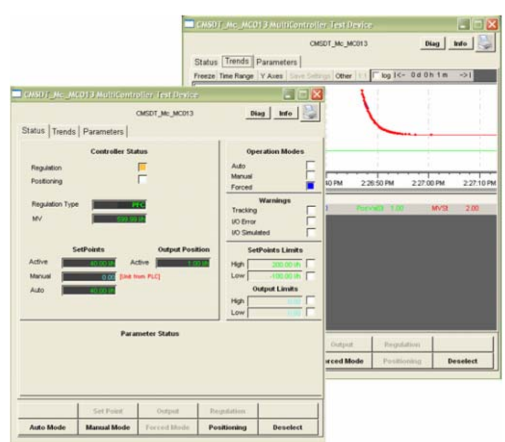


Figure 5: MultiController faceplates.

EXPERIMENTAL RESULTS

The first object implementation of the MultiController into a Schneider PLC solution (Unity) has produced valuable results. The MultiController has introduced advanced control algorithms in a large scale framework project [1, 8]. It offers to experimental plants a way to use new controllers.

Second Order with Dead Time Application Results

$$G(z) = \frac{0.1269z^{-1} + 0.09614z^{-2}}{1 - 1.323z^{-1} + 0.4346z^{-2}} . z^{-3} \Bigg|_{T_e = 1s} \quad (2)$$

Figure 6 shows the process output signal and the control signal in a system driven by (30) with several control algorithms given by the MultiController object.

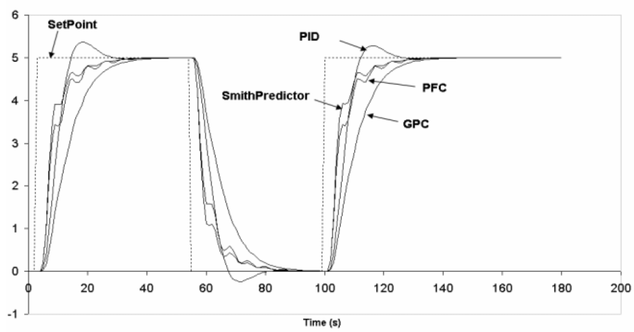


Figure 6: Process output.

Predictive Control Controllers' Results for a Fourth Order System

The experimental tests related to this example highlight the two predictive control algorithms applied by the MultiController to a fourth order system described by :

$$F(z) = \frac{0.01397z^{-1} + 0.08498z^{-2} + 0.04625z^{-3} + 0.002255z^{-4}}{1 - 1.895z^{-1} + 1.336z^{-2} - 0.4152z^{-3} + 0.04793z^{-4}} \Bigg|_{T_e = 2s} \quad (3)$$

Figure 7 deals with the two predictive control algorithms implemented: the GPC and the generalized PFC.

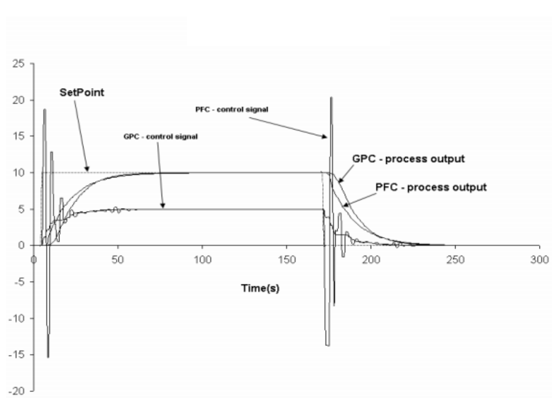


Figure 7: Predictive control algorithms.

CONCLUSION

The MultiController is the combination of an efficient object programming process and advanced control features. By its robust Design, this object is able to capture tuning parameters of all control algorithms through a single custom HMI interface. The PLC MultiController object is a block encapsulating several algorithms. It can be easily extended with others. Its mode management adds better end-user tuning facilities. The PLC object implementation takes into account the cyclic nature of a PLC execution process through the program.

The MultiController object implementation gives alternative solutions to standard PID controllers and increases the available control solutions to solve non-negligible complex problems. The advanced algorithms proposed by the MultiController provide control loop solutions that enable the process control engineer to have access to more expert automation tools [9] [10].The large scale GCS project is then able to use advanced controls algorithms through an efficient PLC-SCADA based environment.

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