Using Wireless Measurements in Control Applications

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ABSTRACT

Wireless transmitters may be preferred in applications where new measurements are required since the cost may be lower than that associated with installing wired transmitters.   However, there is a significant differences in the frequency and manner in which a new measurement value is updated by a wired transmitter vs. a wireless transmitter. Such differences must be taken into account when a wireless measurement is used in closed-loop control. In this paper we examine how the PID has been modified to address control applications using wireless devices. The differences between this modified PID, known as the PIDPlus, and the traditional PID are discussed. Test and field test results are presented that show that the same quality control as wired PID can be provided by PIDPlus despite slower, non-periodic wireless measurement update and communication interruptions.

INTRODUCTION

The recent introduction of wireless transmitters and wireless actuators in the process industry has sparked new interest in control techniques using non-periodic information updates [2, 8]. The underlying assumption in process control has always been that control is executed on a periodic basis and that a new measurement value is available for each execution. However, to minimize power consumption a wireless transmitter may transmit a new measurement infrequently and/or only if the measurement has changed significantly. Thus, to effectively utilize a wireless measurement, the feedback control must be designed to work with wireless measurement.

The use of wireless transmitters in closed loop control presents many technical challenges when the measurement is used in closed loop control. The measurement provided by such devices is often reported on a much slower basis (e.g. 15 second update rate) than that provided by a wired transmitter. Also, the measurement value provided by a wireless device may be communicated on a non-periodic basis. For example, Windowed communications supported by some WirelessHART devices may transmit new measurement values on a non-periodic basis. Also, for any wireless implementation it is important that the control automatically treat loss of communications in a manner that does not introduce a process disruption. To address these issues the PID algorithm may be modified to correctly work with slow measurement updates, non-periodic measurement update and loss of communication. For example, the PIDPlus capability [7] of the DeltaV control system illustrates the PID modifications for closed loop control using a wireless transmitter. In this paper, we show details on how the PID can be modified for feedback control using a wireless transmitter. Also, information is provided on how the PIDPlus preforms using the slow, non-periodic measurement updates and loss of communications.

The paper is structured as follows – section 2 outlines the technical challenges of wireless control. Section 3 provides an overview of PID modifications, PIDPlus, for wireless control. Section 4 compares the test results using PIDPlus with a wireless transmitter vs. PID using wired transmitter, and Section 5 presents field tests results for wireless control of a stripper column.

WIRELESS CONTROL CHALLENGE

Utilizing wireless communications in closed loop control presents many technical challenges [6]. Since most wireless transmitters are battery-powered, it is desirable to minimize how often a measurement value is sensed and communicated to reduce transmitter power consumption. However, most multi-loop controllers used in DCS systems today are designed to over-sample the measurement by a factor of 2x to 10x to avoid the restrictions of synchronizing the measurement value with the control. Also, to minimize control variation, the typical rule of thumb is that feedback control should be executed 4x to 10x times faster than the process response time, i.e. process time constant plus process delay. Also, an underlying assumption in conventional PID design is that a new measurement value is available each execution and that control is executed on a periodic basis. The measurement update and control execution that are typically assumed in a traditional control application using wired transmitters as illustrated in Figure 1.

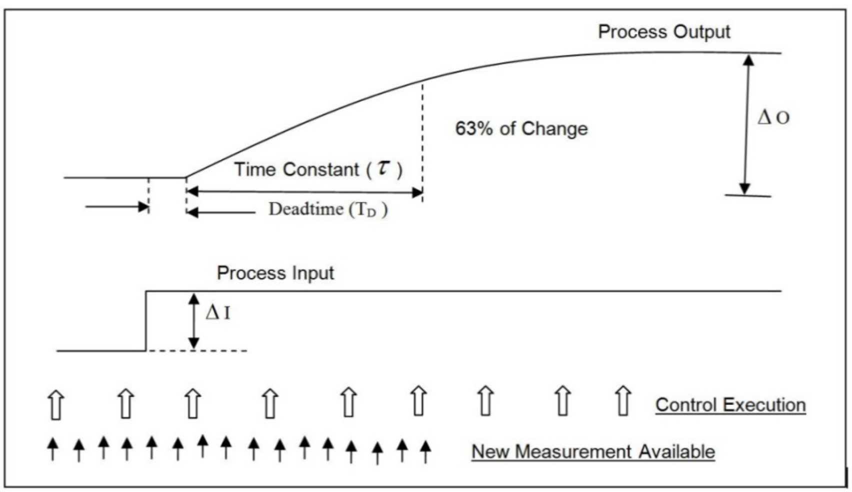

Figure 1. Traditional Measurement Update and Control Execution

If this traditional approach is taken in scheduling wireless transmission to over-sample the measurement by a factor of 2x to 10x, the power consumption will be excessive for all but the slowest types of processes. Slowing down the control execution to reduce the power consumption associated with communication may increase control variability when the process is characterized by frequent unmeasured disturbances. Ideally the power consumption could be minimized by transmitting the measurement value only as often as required to allow control action to correct for unmeasured disturbances or changes in setpoint.

Examples of communication techniques utilized by wireless devices are contained in the HART 7 specification. This specification, adopted as an international standard, IEC 62591, defines five defined burst message-triggered modes. Two of these communication techniques best fit control applications:

Continuous – The device wakes up at a configured update period, senses the measurement and then communicates the value.

Window – The device wakes up at a configured update period, senses the measurement and then communicates the measurement if the specified trigger value is exceeded.

Window communication is the preferred method of communications for control applications, since for the same update period window communications will always require less power that continuous communications. When window communication is selected, a new value will be communicated only if:

- the magnitude of the difference between the new measurement value and the last communicated measurement value is greater that a specified trigger value;
- or if the time since the last communication exceeds a maximum update period.

Thus, the measurement is communicated only as often as required to allow control action to correct for unmeasured disturbances or response to setpoint changes. The windowed mode requires a maximum update period and a trigger value to be configured. In general, the update period should be no longer than one-fourth the process response time. However, a slower update period may be used when it is not critical to immediately respond to a process disturbance.

PIDPlus FOR WIRELESS CONTROL

Two common ways of implementing PI control are shown in Figure 2. In many commercial distributed control systems, the reset contribution of the PID is realized using a positive feedback network (top implementation) in which the time constant of the filter in this network defines the reset time in seconds per repeat. This approach is often taken, since it supports the implementation of external reset for use in cascade and override applications [1, 3, 6].

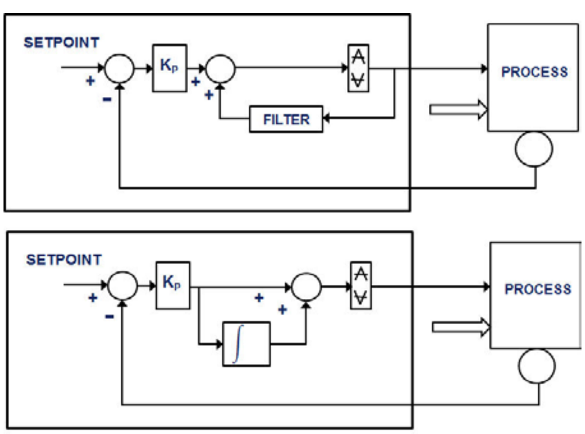

Figure 2. Conventional PI controller implementation

When the measurement is not updated on a periodic basis, the calculated reset action and rate may not be appropriate. If control is only executed when a new measurement is communicated, this could result in a delayed control response to setpoint changes and feed-forward action on measured disturbances that occur between measurement updates. Also, as the PID execution period is increased, the basic assumptions made in the PID design of the reset and derivative calculation may no longer be valid. Thus, to provide best control using a wireless measurement, the PID must be restructured to correctly handle continuous measurement updates communicated on a non-periodic basis and/or much slower than 4 times the process response time.

It may at first appear that there is no technical solution that minimizes how often a measurement is communicated without compromising control performance. The key to understanding how the PID must be modified is to realize that when the PID reset is implemented using a positive-feedback network, the filter-time constant is a direct reflection of the process dynamic response. Based on this understanding, the reset calculation of the PID may be modified [5] for wireless control as illustrated in Figure 3.

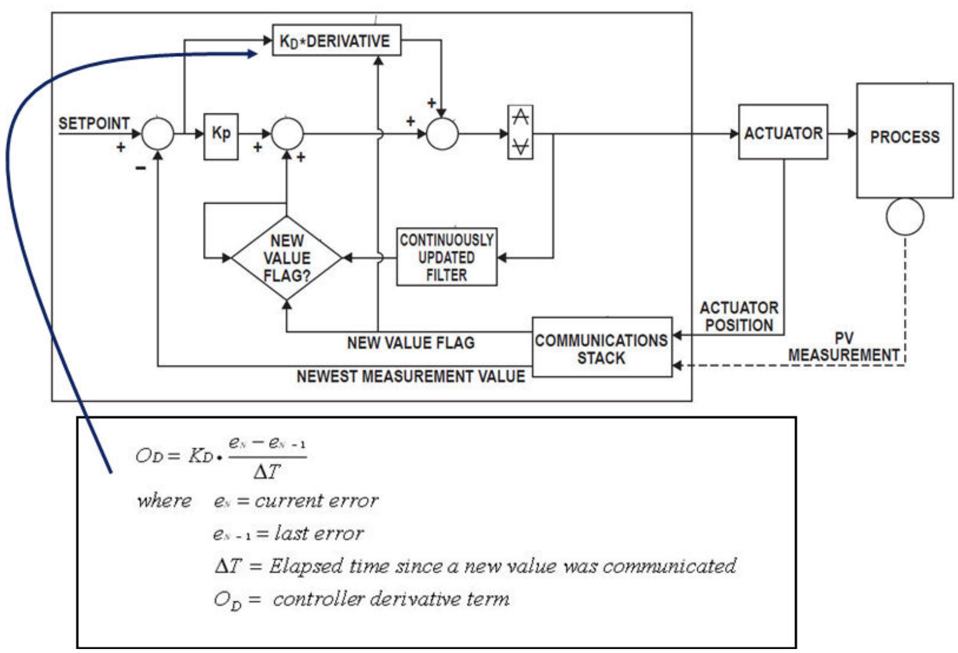

Figure 3. PIDPlus implementation

In the PIDPlus implementation, the positive feedback network used to create the reset contribution is modified to have the following behavior.

1. Maintain the last calculated filter output until a new measurement is communicated.
2. When a new measurement is received, use the new filter output as the positive feedback contribution.

For those processes that require derivative action, its contribution to the PID output should be recomputed and updated only when a new measurement is received as discuss. The derivative calculation should use the elapsed time since the last new measurement.

In the PIDPlus implementation the reset calculation automatically compensates for setpoint change and measurement update rate. The derivative component accounts for a new measurement value not being available each execution of the PID. Thus, there is no need to modify tuning for wireless control.

CONTROL PERFORMANCE COMPARISON

When the PIDPlus is used with a wireless transmitter in a control application, the performance will be comparable to that achieved using a wired transmitter. To illustrate this performance, the closed loop response of the PIDPlus was tested for changes and unmeasured process disturbances where the wireless transmitter utilized Window communications as illustrated in Figure 4.   In these tests, the performance was compared to a standard PI controller where the wired measurement value is communicated as frequently as the PI control algorithm executes.

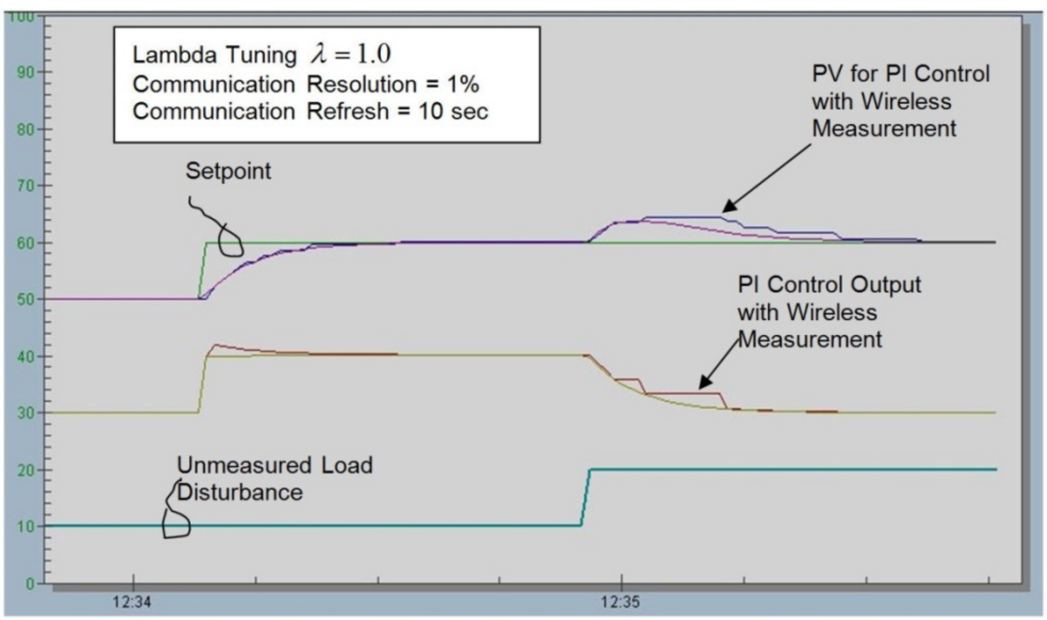

Figure 4. Control for Wireless Measurement

In this example, window communications reduced the number of communications by over 96 % when compared to the number of new measurement values used in control using the wired transmitter.   In Table 1 the difference in control performance is shown in terms of Integral Absolute Error (IAE) for periodic measurement update vs. non-periodic.

Table 1 – Communications and Control Comparison

Communications/Control	Number of Communications	IAE
Periodic /standard PI controller	692	123
Update Using communication Rules/ PI controller for Wireless	25	159

The power for the transmitter can be significantly reduced when slow periodic and/or window communications and the PIDPlus are used with wireless control applications. This reduction in power requirement increases the potential for the number of control applications that may be addressed using wireless transmitters.

The reliability of device communication such as WirelessHART has been well established. Even so, in the event of loss communication, the expected control behavior is of interest. In the following example the behavior of the PIDPlus for loss of communications is compared to a PID with a wired transmitter where the measurement value is frozen for the same period of time. The response observed when the measurement was lost during recovery for a setpoint change is shown below.

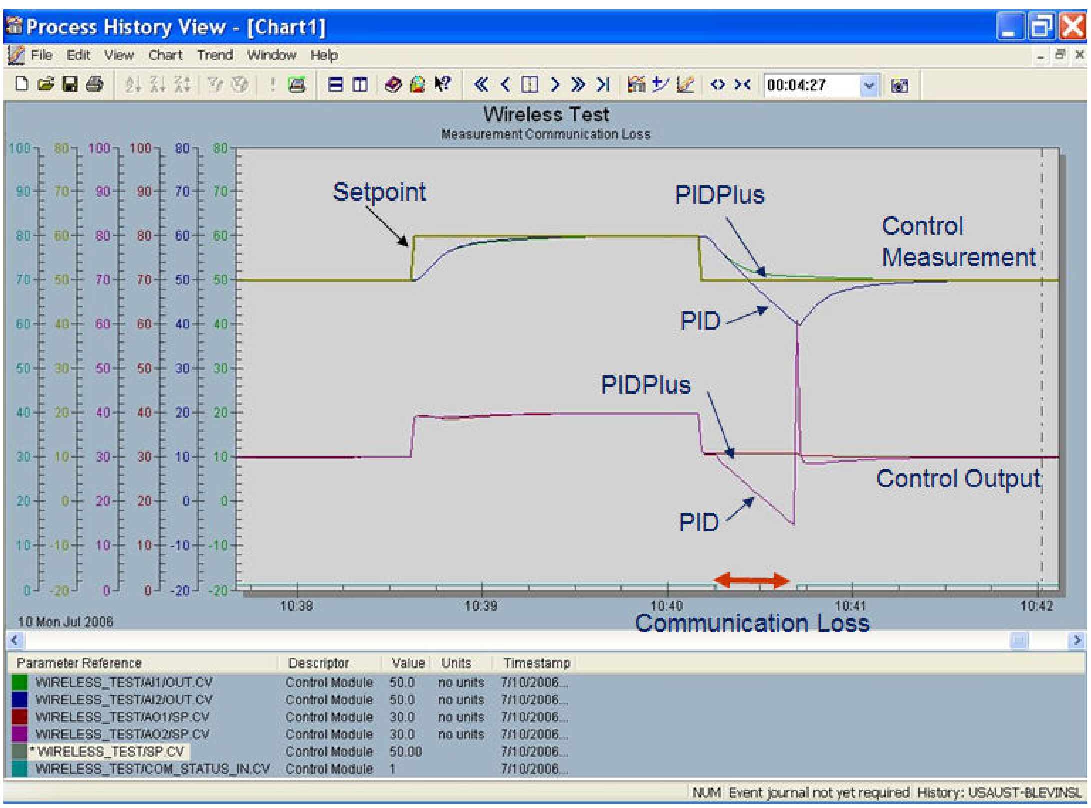

Figure 5. Response for measurement loss

As illustrated by this example, the PIDPlus provides improved dynamic response compared to the PID for the same conditions.

FIELD RESULTS

During the development of the PIDPlus, the control performance using slow periodic communications, window communication was tested extensively using a simulation environment. Also, the performance was verified in several field trials where the PIDPlus was used for control using WirelessHART transmitters. The control of a Stripper Column shown in figure 6 was addressed in the field trial conducted at the J.J. Pickle Research Campus, University of Texas [7].

Figure 6. Stripper and absorber column at UT

Standard WirelessHART pressure and flow transmitters were installed to demonstrate and test control using the PIDPlus. The control system was configured to allow the operator to switch between control using WirelessHART and PIDPlus and the wired transmitters and PID. The stripper column pressure control is shown in Figure 7 for each manner of control.

Test #1

Test #2

Figure 7. Stripper column pressure control – wired vs. wireless using PIDPlus

The same dynamic control response was observed as illustrated in these screen captures. For these tests, the same tuning was used for both wired and wireless control. The control performance for column pressure and steam flow control is summarized in the following table for wireless vs. wired control.

Table 2. Field evaluation of wireless control

LOOP	FIC202	PC215	FIC202	PC215
Select Input	WIRED ON	WIRED ON	WIRELESS ON	WIRELESS ON
Wired Input	511.32	24.01	504.04	24.00
Wireless Input	518.69	24.02	509.66	24.01
RESET_CALC	0	0	0	0
IAE	9134.33	145.46	10645.15	198.60
NUM_COM	13655.00	6649.00	1184.00	912.00
TEST_TIME	6830.00	6829.00	5926.50	5925.00
Time Since Last Update	0.00	0.00	3.50	3.00

Test #1 Test #2

Comparable control as measured by IAE was achieved using WirelessHART measurements and PIDPlus vs. control with wired measurements and PID. However, the number of measurement samples with WirelessHART vs. wired transmitter was reduced by a factor of 10 times for flow control and 6 times for pressure control – accounting for differences in test duration.

CONCLUSION

A method for dealing with slow periodic and/or non-periodic measurement updates is a requirement when closed loop control is implemented using wireless transmitters. Field experience using WirelessHART with PIDPlus in control applications may be summarized in the following manner:

- Wireless measurements may be used in closed-loop control applications.
  - Window communications mode minimizes power consumption
- The performance of PIDPlus in a wireless control network is comparable to PID with wired inputs.
  - PIDPlus handles lost communications better than conventional PID.
- PIDPlus tuning depends only upon process dynamics, not on wireless update rate.

For best control performance process disturbances, the guideline provided for update period should be observed. If disturbance response is not critical, then a slower update period may be used.

REFERENCES

[1] K.J. Åström, and T. Hägglund, in *Advanced PID Control*, ISA, 2006., pp. 85-86

[2] K.J. Åström. "Event based control", in *Analysis and Design of Nonlinear Control Systems*, Springer Verlag, 2007, pp.127-147

[3] T. Blevins, and M. Nixon, in *Control Loop Foundation – Batch and Continuous Processes*, ISA. pp. 266, 270, 393

[4] T. Blevins, (2012) "PID Advances in Industrial Control", IFAC Conference on Advances in PID Control PID'12, 2012

[5] S. Han, X. Zhu, K.M. Aloysius, M. Nixon, T. Blevins, D. Chen, "Control over WirelessHART Network", 36th Annual Conference of the IEEE Industrial Electronics Society, 2010

[6] F. G., Shinskey, "The Power of External Reset Feedback", *Control*, ,May, 2006, pp.53-63

[7] F. Siebert, and T. Blevins, "WirelessHART Successfully Handles Control", *Chemical Process*, January, 2011

[8] M. Rabi and K. H. Johansson. "Event-triggered strategies for industrial control over wireless networks", In Proceedings of 4th Annual International Conference on Wireless Internet, Maui, Hawaii, USA, 2008.