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The Impact of the Block Model Concept in Fieldbus Systems: Control System and Instrument become One

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The Impact of the Block Model Concept in Fieldbus Systems: Control System and Instrument become One

By James Powell, P. Eng.

In fieldbus systems, instrumentation is now an integral part of the control system and now appears to the control engineer as a series of blocks

When I started as a controls engineer, instruments were simply black boxes out in the field that provided information. They were the domain of the instrumentation technologist. I assumed the instruments provided accurate information, and I did not concern myself with these devices unless some sort of problem occurred.

Fieldbus technologies[1] such as PROFIBUS PA and FOUNDATIONTM Fieldbus have changed this situation by introducing the block model into the instrument. Today's more sophisticated instruments have DCS (Distributed Control System) structures built-in. This allows them to be fully integrated into the control system, giving the operator a more detailed view of the devices. The use of the block model structure logically results in many benefits, and the impact is revolutionary.

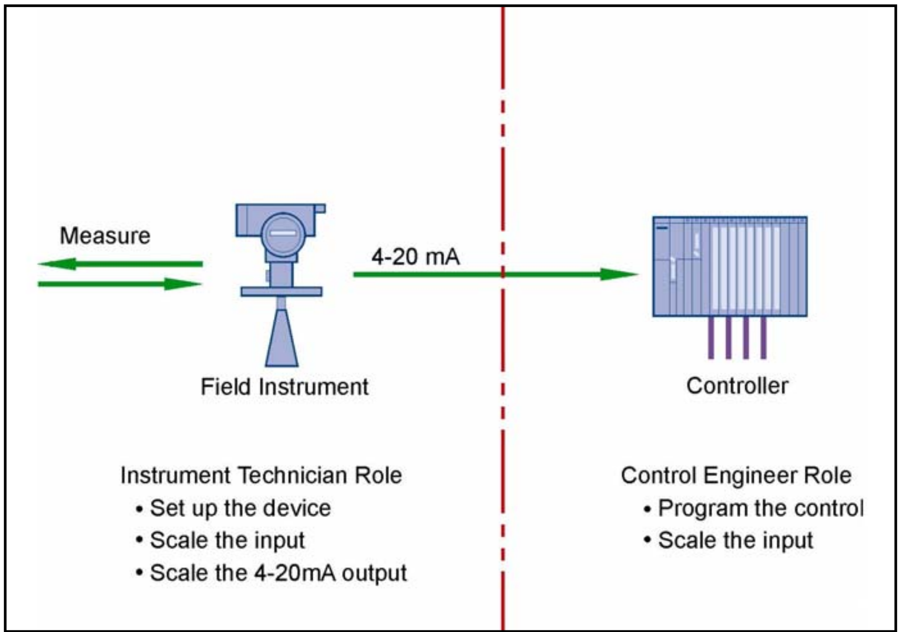

Figure 1: Old relationship between instrument and control system

Relationship between Instrument and Control System

In the older, more traditional control systems, there was a clear division between the field devices and the control system. The instrumentation technologist looked after the field devices and the control engineer just had to scale the 4-20 mA analog value (non-HART)[1] coming into the control system (Figure 1). The control engineer still checked the accuracy and response rate, but did not concern himself too much with the details of the instrument.

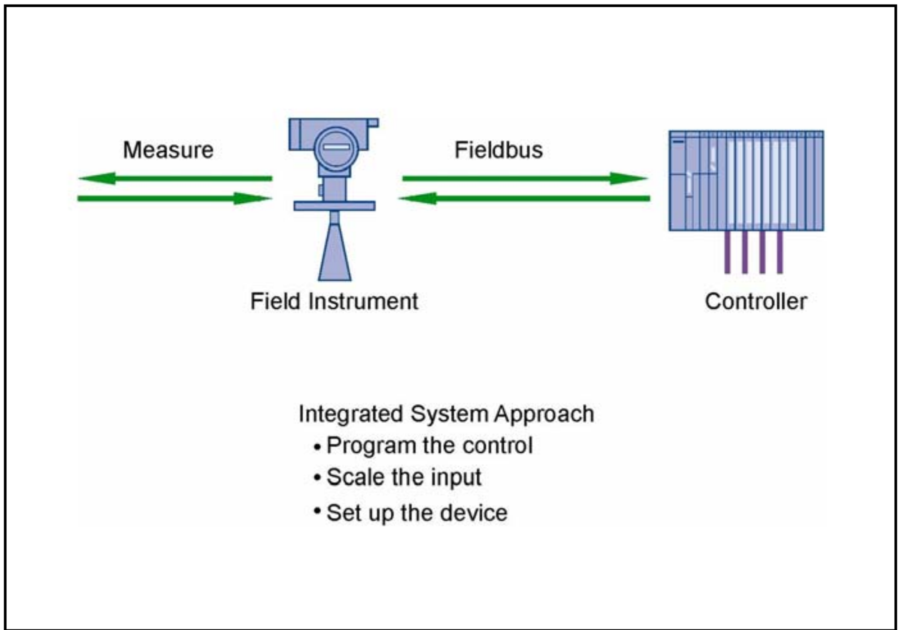

Figure 2: New relationship between instrument and control system

Now with PROFIBUS PA and FOUNDATION Fieldbus, the instruments are very much part of the system and the engineer has full control of the devices (Figure 2). From the engineer's point of view, there is now no distinction between the instruments and the control system. It's an integrated whole.

Programming the Instrument (Block Model)

For the computers that run large DCS or PLC control systems, a type of computer language has developed that uses predefined "blocks". This is a computer language that control engineers are accustomed to. It can go by many names such as FBD (Function Block Diagram) or simply Block Diagram.

The blocks have inputs and outputs, and are programmed graphically by simply drawing lines between the blocks. Each block performs a function or a series of functions. You read the block diagram from left to right, top to bottom. One block flows into the next block. Some blocks will stop the flow on that line depending on the result of a calculation. You can also define a complicated block by 'connecting' a series of simpler blocks. Thus, you can have levels of programming.

Figure 3 shows a simple example of this sort of computer language. Starting on the left, the first block is a compare function. It compares the two entries to see if one is larger than the other. In this case, it is checking to see if variable Tank 1 Level is greater than 4.5 meters. If this is true, the block that is connected to it will be executed. This second block is a "set" block that will, for example, turn on pump 1. If the level is not greater than 4.5 meters, the block to the left is not executed and the pump remains off. This simple example could be expanded into a pump control algorithm and combined to make one block called "Pump Control." This is an example of a complicated block made up of simpler blocks.

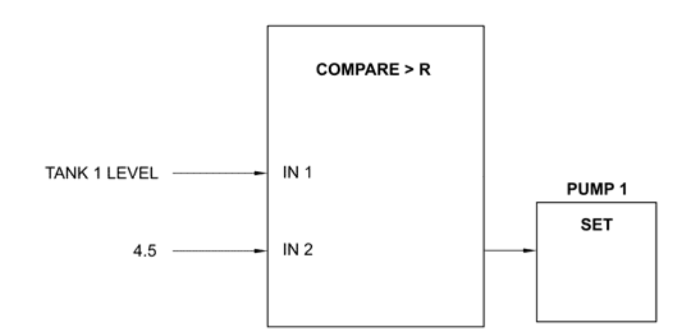

Figure 3: Example of a block program to monitor a level indicator

For both PROFIBUS PA and FOUNDATION Fieldbus, the instrument itself is now viewed as being made up of a series of blocks. Figures 4 and 5 give the example of a PROFIBUS PA radar device.

In Figure 4, we see that sensor information is fed into a transducer block, which then sends information into analog input function blocks. Notice that the analog blocks are called "input" blocks. They are called "input" because we are viewing information flow from the control system's point of view. These analog input blocks are similar to the analog input blocks for a 4-20mA input except that, in this case, they do not run in the main controller and they provide status information as well.

The transducer block is also defined in terms of blocks as shown in Figure 5. All of these blocks (with the exception of the sensor technology block) are defined in the PROFIBUS Profile Standard version 3.3

As with subroutines in most computer languages, the values passed between blocks also have a status indicator that lets you know that the calculation (or in this case, the process variable) is OK. This 'status indicator' is a logical result of using the block model structure. The blocks can also perform self-diagnostics, alerting the control system to any kind of problem in the instrument itself.

In the case of PROFIBUS PA, this status indicator takes the form of a status byte that is reported alongside the process variable. Figure 6 shows the output for a radar level instrument.

Using blocks, control engineers see the instrument presented in a language they know. Some code that was previously executed in the main controller is now executed in the instrument itself. In fact, from the control engineer's point of view, where the code is executed makes no difference since it is really just one system to look at and modify at will.

Impact on the Instrument Manufacturer

As figures 4 and 5 show, the block mod-el is highly structured and has a number of pre-defined segments or blocks. A manufacturer can add the required blocks to the instrument and express the current functionality of the instrument in terms of a block structure. Alternatively, the manufacturer can change the functionality of the device to match the published block model standard.

For FOUNDATION Fieldbus, only the first option is possible because Fieldbus has not yet released a complete transducer block standard. It is currently in development.

For PROFIBUS PA, the second option is the better choice since PROFIBUS PA has defined the transducer block in its Profile Standard. A device Profile is a standardization of the device from a network point of view for the purpose of data exchange, configuration and functionality.[4]

PROFIBUS has defined two device classes as part of its profile standard. A Class A device conforms to the block structure but does not conform to the full definition of the

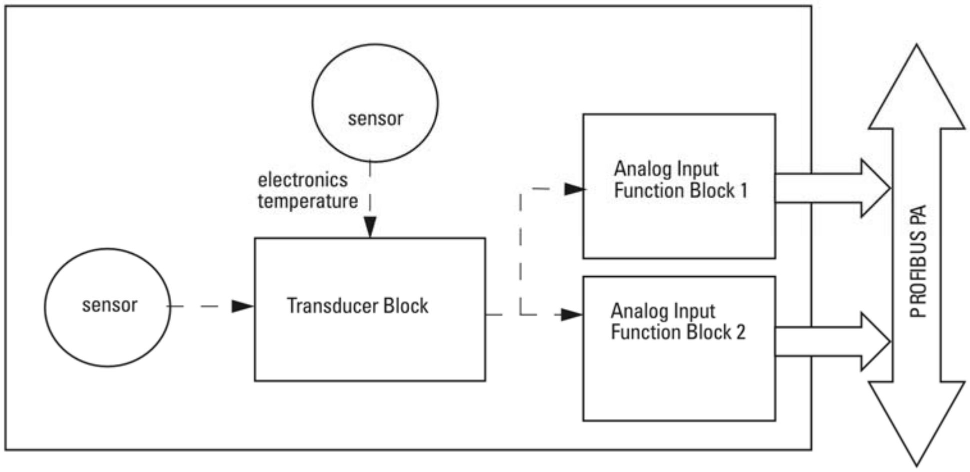

Figure 4: Block model of a radar level instrument[2]

transducer block. That is, it would not use the standard parameters like those shown in figure 5 for a level device. It would still have a transducer block, but this would be defined by the manufacturer. In this case, the manufacturer could take an existing product and just add code for the additional blocks.

A Class B device conforms to the block structure and the full definition of the transducer block. This class of device encourages the manufacturer to change5 the instrument's code and functionality to match the standard.

If, for example, you compare two PROFIBUS PA Class A level devices, functions blocks in Figure 4 would apply, but not the function block and parameters in Figure 5. There would be a transducer block, but the parameters (input/outputs) shown in Figure 5 would not apply.

If you compare two PROFIBUS PA Class B devices, function blocks in Figure 4 and 5 would apply, and the sub-blocks in figure 5 would work the same with the exception of the sensor technology block. This level of standardization has numerous advantages to the end user6.

Impact on the end user

With the removal of the boundaries between instruments and control system, the end user will gain some tremendous benefits that often translate directly into cost savings.

With the control engineer programming the analog input block in the device and also setting up the transducer block, scaling can now be done by one person in one spot. Previously, you needed to perform scaling in the instrument itself and then again in the control system and, sometimes, in multiple places in the control system. Scaling and alarming are now done from a single control point. This greatly simplifies the system set-up, making it quicker and easier. There's no need to spend hours tracing values from instrument to controller to HMI, verifying that they are scaled and alarmed correctly in each location. It removes the potential for errors and speeds up troubleshooting. During commissioning of a plant, this change will save a lot of time and effort and money.

Block programming creates a commonality between different instruments that was not there before. This makes it easy to work with various instruments and cuts the set-up and training costs associated with the system. This commonality is taken to a higher level in PROFIBUS PA with the use of Profiles6.

With instruments now integrated into the control system, there is far more information available to the control program. This can significantly reduce downtime. Previously, you might have to wait for a process upset before you knew that an instrument failed7. If, for example, a level switch failed, you might not discover the failure until you either ran out of material and had to shut down the process, or until you overfilled the tank and had to clean up a mess. Either scenario is costly. Today, you know your level switch has failed because it tells you, and you can take action immediately before it results in a serious problem.

Another benefit of increased information is the possibility for predictive maintenance. For example, a capacitance level switch in some applications has to be cleaned occasionally because of material build-up on the probe. Previously, you had to guess when it would need cleaning. Today, smart sensors can monitor the build-up and tell the control system when they need cleaning. This function is currently being added to the Siemens Pointek CLS 200 and CLS 300 capacitance probes, and was demonstrated at 2004 Interkama.

The cost savings associated with preventing downtime, preventing spills and optimizing maintenance are tremendous.

Challenges

With any major change comes a challenge. Like many technology changes, the challenges are related to helping people adapt to the new technology. The benefits of the technology can only be realized if the people involved know how to maximize it.
The main challenge with the systems approach is educating people about it and getting them to change the way they work.

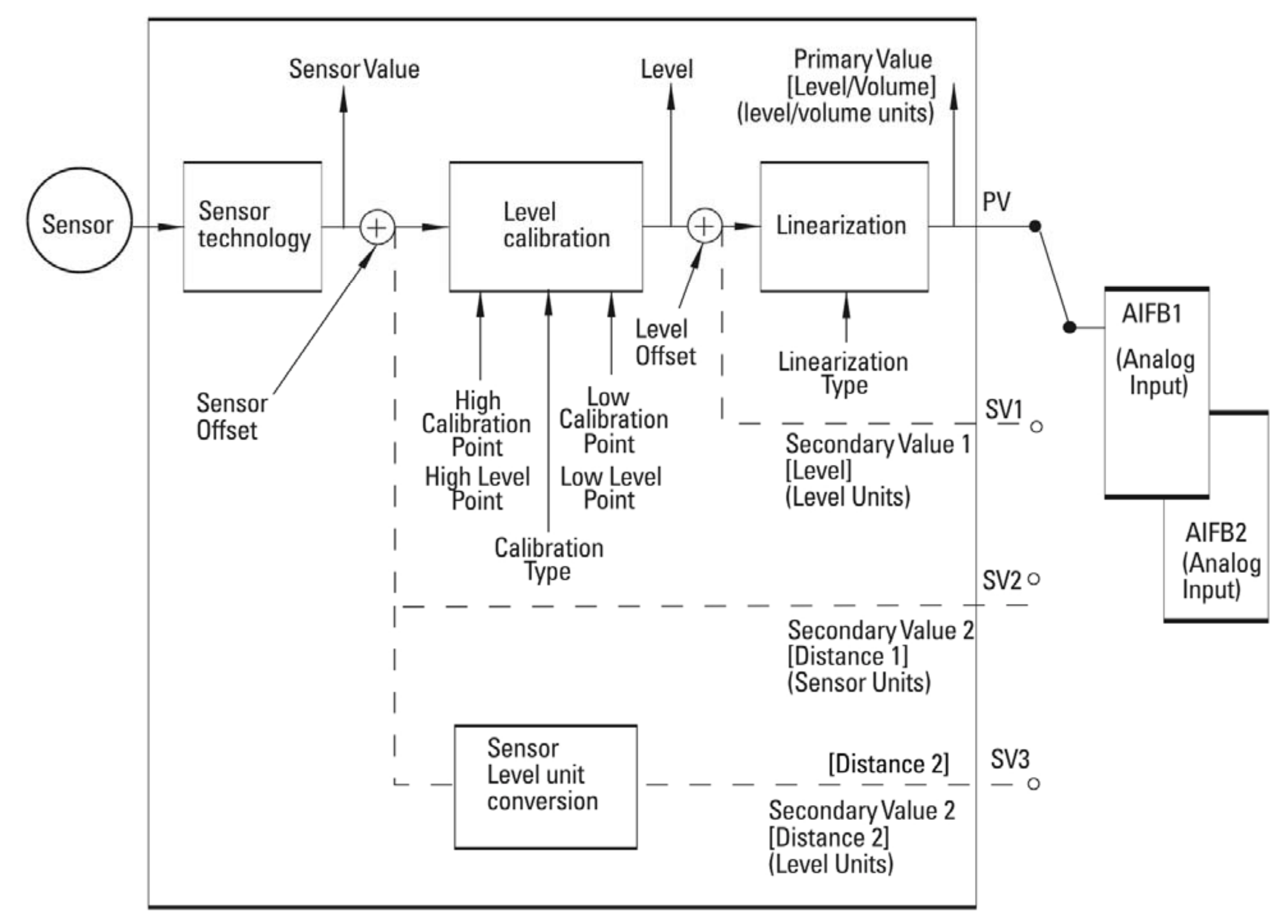

Figure 5: Block model of a radar level transducer block[2]

Although control engineers and instrumentation technologists have always worked together, each group has had its own tools and domain. Now, the instrument technologist needs access to the control system for set-up and monitoring of the instruments. The technologist also needs to understand the block model as the control engineer does. This completely changes the way the two groups of people work together and will require far more co-operation than ever before.

With more device information available, instrumentation maintenance functions are radically changed. The ability to proactively plan maintenance schedules and react immediately to an impending field device problem will help significantly reduce downtime. But this is a new way of working that represents a major shift in mindset that some will welcome and others may resist. The benefits can only be realized if technicians and operators are well trained on these new tools and use them effectively.

Conclusion

Fieldbus technologies such as PROFIBUS PA and FOUNDATION Fieldbus have brought field instruments into the domain of the control system, making them one system. This has changed a lot of things:

- The way the instrument is programmed
- The way the instrument works
- The way the system works
- The way control engineers and instrumentation technologists work
- The way maintenance is done

In short, it is a revolutionary change. With this comes the potential for great benefits in efficiency and cost savings for those who adapt to this new way of working.

Notes:

1 The HART® protocol is only now starting to introduce the block model structure, and is not discussed in this article. When we refer to 4-20 mA, we are not talking about HART, we are referring to just a 4-20 mA analog signal.
2 Drawings are taken from the Siemens SITRANS LR 200 manual as adapted from the PROFIBUS-PA Profile for Process Control Devices Version 3.0 October 1999, PNO order number 3.042.
3 PROFIBUS International publication "PROFIBUS Profile, PROFIBUS-PA, Profile for Process Control Devices" Order No. 3.042.
4 International Electrotechnical Commission (IEC) Standard TS 61915:2003, page 15.
5 The manufacturer could still re-map his current parameter set to the pre-defined parameter set of the profile using a linear transformation; however, this could get very messy and is not really a good way to go about it.
6 The Benefits of the "Profile" Concept in Fieldbus Technology, James Powell, ISA 2004 Expo Transactions.
7 4-20 mA signals will go to a value outside of the 4-20 mA range to notify the user of some error conditions. This sort of functionality is not in all 4-20 mA devices and is not implemented in all input cards. Also, if the device fails, it might still go to value that the input card thinks is OK. With the digital buses, you have far more information available. It does not matter how the device fails; you will just know it has failed.

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