Application and Benefits of an Open DeviceNet Control System in the Forest Products Industry


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Abstract – This paper describes how smart devices communicating on a DeviceNet protocol have allowed a composite panels plant to successfully integrate vast amounts of process information to improve productivity and uptime. The benefits of integrating DeviceNet systems include better process information to operators and improved diagnostic capability for troubleshooting. Valuable process information, previously unavailable, can now be readily viewed by any mill personnel. Safer plant operation has also resulted from the additional process control information. Also discussed is the total installed cost of a DeviceNet system as compared to a traditional PLC installation.

I. INTRODUCTION

Until 1996, the Weyerhaeuser Particleboard plant in Springfield, OR was installing conventional PLC I/O systems. However, as the machine centers grew more complex and as the plant personnel looked for more information about their equipment, a new control strategy was adopted. A new industry open protocol, DeviceNet, was chosen as an alternative to traditional PLC I/O. DeviceNet allowed for a distributed control system with the potential of interfacing to smart devices from many different vendors. Today, the plant is utilizing DeviceNet on three different processing systems, with the largest single PLC processor communicating with nearly 420 nodes.

A. Manufacturing Process Overview

The Springfield plant is capable of producing particleboard from ¼” to 1 3/16” in both commercial and industrial grades. Metric panels from 9 mm to 30 mm are also produced for overseas markets. The plant operates 24 hours a day, 7 days a week.

The mill utilizes sawdust, wood shavings, and wood chips for its raw materials. The wood is sorted by size and type. The smaller sized material is used for the surface and the larger material is used for the core of the product. Oversized material is milled to the proper dimension and dried in large rotary drum dryers. The dryers are heated by natural gas and supplemental heat is provided by burning sander dust, a by-product of the manufacturing process.

Once the material is of proper size and moisture, it is blended with resin and other chemical additives. Metal sheets 5 feet by 24 feet are used to form the particleboard mat. First the bottom surface layer is laid on the sheet. Then the core material, followed by the top surface layer. At this point, the mat is 3 to 4 inches thick.

The mats are conveyed to a large 14 opening steam-heated press. As the press closes, the heat and pressure cures the resin in the mat to form a solid panel. After 2 to 10 minutes, depending on the thickness of the product, the press opens and the boards are pulled out of the press and sawn to rough size.

After the panels have cooled for a short time, they are sanded to final thickness and a smooth finish is applied. The product is then sorted by grade and quality. On-grade panels are sawn to final size and packaged for shipment.

The mill, built in 1969, has undergone many modernization projects. Most of the mill is now on PLC control and is tied to a mill-wide fiber-optic based local area network (LAN). In the last couple of years, the introduction of DeviceNet has increased the availability of process information from the plant-floor.

II. OPEN DEVICENET PROTOCOL

DeviceNet is a low-cost, open communication network that links intelligent control devices over a byte level system. A byte level system is optimized for machine control, balancing network speed and data throughput. The simple trunk and dropline networking solution not only reduces wiring costs, installation time, and downtime, it also enhances the ease to interchange conventional and complex devices.

DeviceNet is built around a published, open standard, so any company can develop DeviceNet devices without paying a royalty. The rapid growth, provided by the open standard, benefits customers most with competitive pricing and a wide availability of components.

Some typical DeviceNet applications include:
- Conveyors
- Machine tools
- Transfer lines
- Packaging and material handling
- Robotics
DeviceNet is an open protocol supported worldwide by the Open DeviceNet Vendors Association (ODVA). This association is comprised of over 250 member companies throughout industry, with a common objective of establishing an open network standard, upon which all of their various products can communicate with. Typical products compatible with DeviceNet include plant-floor devices, sensors and actuators. The network is based on the Controller Area Network (CAN) technology, an open, commercially available chipset.

ODVA is an independent association made up of hardware and software vendors, and customers. The purpose of ODVA is to develop and foster standards for devices, software, and a network for byte level (machine control) communications. ODVA works with vendors and provides assistance through developer tools, training, compliance testing, and market activities. Membership is open to all interested individuals, groups, and companies.

As a Device Network, DeviceNet is considered a “byte” level network. It is, however, applied in control situations requiring anything from simple on/off control to information and batch process control. See Table I and Fig. I for details on device level network architecture and applications.

### TABLE I
Comparison of the various available device network architectures.

<table>
<thead>
<tr>
<th>Type</th>
<th>Characteristics/ Application</th>
<th>Description</th>
</tr>
</thead>
</table>
| Bit  | High speed, low diagnostics system. | A system where bit-sized information packets are passed.  
*Examples:* Limit switch passing on/off data and a photoelectric eye passing active/inactive signals. |
| Byte | Optimal for machine control. | A system where byte-sized information packets are passed. DeviceNet uses 0 - 8 bytes. This intermediate communication size provides for rapid scan times, quick response, and some limited explicit message traffic.  
*Example:* Devices passing multiple data segments, analog signals, or status messages; roughly 1 - 3 stations on an assembly line. This is ideal for devices such as bar code scanners, current signals, etc. |
| Process | Used for building and plant control. | A complex system where large amounts of information are transmitted. |

A. DeviceNet Connections and General Specifications

A typical connection diagram for various types of DeviceNet compatible devices is shown in Fig. II.

General specifications for DeviceNet are shown below.

- Total lengths: 1640 ft, 828 ft, 328 ft (500 m, 250 m, 100 m), depending on network speed
- Drop line length: 20 ft (6 m)
- Power drop line length: 10 ft (3 m)
- 24 VDC power
- Mis-wiring protection
- Node insertion/removal under power
- Supports a mixture of open screw terminals, sealed mini and micro connectors
- Multiple power configurations
- Vendor interoperability

![DeviceNet Connections and General Specifications Diagram](image-url)
III. PROCESS CONTROL STRATEGY

The manufacturing process at Springfield utilizes a three-tiered process control strategy:

- **Device Layer** – Provides communication to the field devices.
- **Control Layer** – PLC to PLC communication.
- **Information Layer** – Supervisory control system LAN and communication to Human Machine Interface (HMI) stations.

At the Device Layer, the plant utilizes both standard PLC I/O racks and DeviceNet compatible I/O. Standard field devices such as limit switches and pressure transmitters are wired into traditional PLC racks. Recent projects have integrated DeviceNet into the control strategy. A total of 18 DeviceNet networks are currently in operation in various parts of the plant. The most extensive system is in the raw materials screening and milling PLC, with nearly 420 nodes. On that system alone, an estimated 3900 discrete, analog, and status points are being generated by the DeviceNet nodes.

The Control Layer utilizes a 115k baud Data Highway to tie all eight of the PLCs together. This network is used for interlocking between the various PLCs as well as PLC programming and troubleshooting.

All of the PLCs are also linked into a plant-wide Ethernet LAN, which comprises the Information Layer. Seven 100Base-FX fiber optic segments interconnect the various machine centers. Each machine center has a 10/100Base-TX hub to interface the PLCs with the HMI stations. A total of 18 HMI stations are used throughout the plant for equipment control and monitoring. Each HMI station is configured identically so that any machine center or monitoring station can view the other processes. Control of the area is gained by logging onto the appropriate operator screens.

In order to ensure the best performance, all of the HMI stations run 100 Mbit to their local hubs. Areas with high concentrations of HMI stations utilize Ethernet Switches to isolate high data traffic.

A. DeviceNet Selection Process

DeviceNet was first installed in 1996, a solution to problems that developed with the installation of a new sanding line. Originally, the system was designed with the intent of using small footprint, distributed I/O racks communicating on conventional Remote-I/O. These racks were to be mounted on the equipment. The goal was to minimize long wire runs back to the PLC and reduce start-up time by having the manufacturer commission the I/O at their factory. Upon installation of the equipment on-site, only the communication line to the various racks would have to be wired and it would be ready to run.

It became evident during the design stage that the number of racks required left little room for future expansion. Rough calculations on PLC scan time looked dismal as well. With the large number of racks, it was becoming evident that the PLCs ability to scan and solve logic could be a major issue. Instead of adding a second PLC to split the processor load and increase the available rack space, consideration of a different control scheme began.

The new control scheme had to have a minimum impact to the mill’s overall control topology. There was already a substantial investment in the existing PLCs, including the Data Highway and Ethernet networks. In addition, the maintenance team was very familiar with the PLC programming and troubleshooting software. The new system had to fit right into the existing PLC system and still provide the benefits of an open system. DeviceNet fit the criteria.

DeviceNet was selected for its ability to interface to the mill’s existing PLC system. The existing PLC platform could be utilized and still take advantage of an open system. From a programming standpoint, the DeviceNet system was relatively seamless. The ladder logic looked exactly the same, except that the data now resided in integer file space instead of the standard input and output files. (As an example, an input in DeviceNet would be represented as N9:100/05 instead of I:100/05.) Once the maintenance team learned the difference in mapping I/O, troubleshooting and maintaining the PLC program was not an issue. With DeviceNet, the existing Data Highway and Ethernet infrastructure would not have to be touched.

Growing acceptance of DeviceNet and the availability of many products were also key. The potential for future products to pull in lots of process data without additional wiring was also key to the decision. Many vendors at the time were indicating that smart motor starters, limit switches, and other field devices were on the horizon. Finally, the ability to choose from different vendors was particularly appealing.

Since the decision to utilize DeviceNet occurred part way through the design phase, only the motor control center (MCC) I/O was converted to DeviceNet. All starting and stopping of the motors were performed over a single 125k baud DeviceNet network. At the time, intelligent motor starters were not available and only discrete start/stop functions were implemented. The sander line project used 25 modules. Each module supports 8 inputs and 8 fused outputs.

B. DeviceNet Integration

The first several DeviceNet projects only used discrete 8 input/8 output modules. These systems took advantage of the highly distributive feature of DeviceNet but did not include any “smart” modules that provided additional data.

In 1997, nearly all the raw materials screening, milling, and conveying systems were revamped. Close to 200 motors were replaced, some as large as 200 HP. In addition to replacing mechanical equipment, it was decided that the PLC I/O racks were to be replaced with DeviceNet modules.
There were several reasons for the overhaul:

- Much of the existing control wiring had been installed over a number of years and needed to be “cleaned-up.”
- Some of the I/O racks lacked up-to-date documentation. Troubleshooting was an issue.
- The extensive nature of the project, it was decided that replacing the I/O with DeviceNet was much more cost effective than re-wiring to the old racks.
- The first several DeviceNet systems ran with very few problems.

Ultimately, DeviceNet modules from 5 different manufactures were integrated into a single PLC system. This clearly demonstrated the open architecture of the DeviceNet protocol. Without any custom programming, many different off-the-shelf products were integrated into a large networked PLC I/O system. The devices that were used are itemized in Table II.

<table>
<thead>
<tr>
<th>Make</th>
<th>Model</th>
<th>Description</th>
<th>Number of Connected Devices</th>
<th>Input/Output</th>
<th>Qty</th>
<th>Installed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allen-Bradley</td>
<td>1771-SDN</td>
<td>DeviceNet Scanner Card for PLC-5 series processors</td>
<td>2 networks of 63 nodes each</td>
<td>n/a</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Cutler-Hammer</td>
<td>1794-ADN</td>
<td>Flex-I/O DeviceNet Adapter Module</td>
<td>Supports 8 Flex-I/O modules</td>
<td>varies</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>SAM</td>
<td>WPONIDNA Advantage Starter Module</td>
<td>1 starter</td>
<td>3 words in 8 bits out</td>
<td>227</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DNS50</td>
<td>Sensor Adapter Module</td>
<td>1 discrete device</td>
<td>1 bit in no outputs</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dodge/Rockwell</td>
<td>EZ-Link Bearing Monitor</td>
<td>1 bearing</td>
<td>4 words no outputs</td>
<td>66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal Control System</td>
<td>ABB Variable Frequency Drive Interface</td>
<td>1 drive</td>
<td>3 words in 3 words out</td>
<td>32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCM</td>
<td>Discrete I/O Block</td>
<td>n/a</td>
<td>8 inputs 8 outputs</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PBM</td>
<td>Pushbutton Panel</td>
<td>n/a</td>
<td>8 inputs 8 lights</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Reserve Control</td>
<td>1782-JDA Analog Input Module</td>
<td>n/a</td>
<td>4 inputs no outputs</td>
<td>16</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

At the heart of any DeviceNet system is the scanner card. The scanner card is responsible for communicating with all of the DeviceNet nodes and transferring the data to the PLC. The installed scanner card is capable of supporting 2 physically separate networks of 63 nodes each.

In an attempt to balance the network traffic with data transfer speed, most networks were held to about 30 nodes. The largest network has 56 nodes and operates without any noticeable delays. Although studies have not been performed, even the largest system reacts fast enough for the process to operate smoothly. The networks were also segmented by process. One processing center would have its own DeviceNet network. This design would minimize overall downtime in the event of a network failure.

1) DeviceNet Starters: The DeviceNet starter module allows for start/stop capability as well as the ability to read the status, current, phase imbalance, and thermal capacity of each starter. The module provides various data models to choose from. The model that was implemented is as follows:

<table>
<thead>
<tr>
<th>Make</th>
<th>Model</th>
<th>Description</th>
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<th>Input/Output</th>
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</tr>
</thead>
<tbody>
<tr>
<td>ABB</td>
<td>Variable Frequency Drive Interface</td>
<td>1 drive</td>
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<tr>
<td>HCM</td>
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<td>4 inputs no outputs</td>
<td>16</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2) DeviceNet Variable Frequency Drives: The Variable Frequency Drives (VFD) are also controlled via DeviceNet. In addition to starting and stopping the drive, the following information is available:

- 3 Words of Data from Each Starter
  - 1 bit AUX Contact
  - 1 bit Starter Warning
  - 1 bit Starter Fault
  - 1 bit Starter Ready
  - 1 bit Control from Network (PLC Control)
  - 16 bits Average Motor Current
  - 8 bits Percent Thermal Capacity
  - 8 bits Percent Phase Imbalance

- 8 Bits of Data to Each Starter
  - 1 bit RUN Command
  - 1 bit Fault Reset

Although some models provided more data, such as current for each phase, this model allowed a wide variety of data from the starter without consuming a lot of bandwidth on the DeviceNet networks.

The PLC utilizes the “AUX Contact” signal and the “RUN Command” in the motor circuit. Critical motors have the average motor current, thermal capacity, and phase imbalance as part of its safety interlock. A separate diagnostic data file created for each DeviceNet network monitors the health of the each module. A bit to indicate whether the module is functional is also interlocked into the motor circuit.
TABLE V
3 Words of Data from Variable Frequency Drive

<table>
<thead>
<tr>
<th>1 bit</th>
<th>1 bit</th>
<th>1 bit</th>
<th>1 bit</th>
<th>1 bit</th>
<th>16 bits</th>
<th>16 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUX Contact</td>
<td>Drive Ready</td>
<td>Drive in Remote Mode</td>
<td>Drive at Setpoint</td>
<td>Drive Warning</td>
<td>Drive Speed Feedback</td>
<td>(Any additional drive parameter. Not currently used.)</td>
</tr>
</tbody>
</table>

TABLE VI
3 Words of Data to Each Variable Frequency Drive

<table>
<thead>
<tr>
<th>1 bit</th>
<th>1 bit</th>
<th>1 bit</th>
<th>16 bits</th>
<th>16 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN Command</td>
<td>Drive Fault Reset</td>
<td>Drive Communication Reset</td>
<td>Drive Speed Setpoint</td>
<td>(Any additional drive parameter. Not currently used.)</td>
</tr>
</tbody>
</table>

3) DeviceNet Bearing Monitors: Historically, the plant has seen many fires caused by overheated bearings. In the raw material expansion project the safety of the plant was improved not only by replacing old equipment, but also by adding on-line bearing monitors. Each bearing monitor provides the following data in real-time:

TABLE VII
4 Words of Data from Bearing Monitoring Module

<table>
<thead>
<tr>
<th>8 bits</th>
<th>16 bits</th>
<th>16 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alarm Bits (not used… all alarms are in PLC and HMI)</td>
<td>Bearing Temperature</td>
<td>Bearing Vibration (1 axis)</td>
</tr>
<tr>
<td>Bearing Speed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

These DeviceNet modules provide additional information to the PLC for safety interlocking. Most of the bearing monitors are programmed in the PLC such that an over-temperature or over-vibration condition will automatically shut down that piece of equipment. The bearing speed indication is programmed to ensure the equipment is actually operating when the motor is energized.

IV. DEVICENET INSTALLED COST COMPARISON

One of the major advantages of DeviceNet is the ability to gather large amounts of process data without significantly increasing project costs. In many of the projects, the increased cost of the DeviceNet modules was offset by the reduced cost of installation. Distributing the I/O meant that long wire runs were not required and often the only long conduit runs were for the single DeviceNet cable. MCC installation costs were minimal since all the structures were pre-wired and tested at the factory.

Although total installed costs of DeviceNet were not known before the project was commissioned, an analysis of the first cost for the major equipment was beneficial after the fact in estimating the incremental installed cost versus a traditional PLC with conventional I/O devices. The following is a cost comparison of a 25 starter, 7 structure MCC line-up. This comparison is based on an actual MCC line-up that was installed in the 1997 raw materials project. The costs have been approximated, but the relative difference in the three cases is accurate. In all cases, the physical MCC hardware is the same. Only the control electronics are different. The analysis is based on examining three different alternatives. The first alternative is a conventional MCC with the PLC processor and I/O in a remote control cabinet. The next scenario is based on purchase of this MCC to include factory mounted and wired PLC remote I/O. The third is the DeviceNet MCC as actually installed at the mill.

A. Alternative 1

The first alternative involves purchasing the MCC structure from the factory without any control wiring. Costs are based on all wiring from the PLC cabinet to each individual starter being performed on-site. The PLC hardware and rack cost is estimated for 2 racks. Each rack has a remote I/O communication module, two 16 point input cards, two 16 point output cards, and a power supply module. The racks are mounted and wired on-site by contractors.

The engineering and design cost for just the MCC is estimated at 8 hours. This would include I/O lists and associated CAD drawings. Start-up for the MCC would be estimated at 6 hours to check wiring and PLC connectivity.

B. Alternative 2

A slightly less expensive solution is to have each of the starters wired to PLC racks at the MCC factory. In this alternate, the PLC rack is mounted in one of the MCC structures. All that is required on-site is to run a communication line to the PLC rack. The PLC hardware cost in this scenario is the same as Alternate 1, but the overall field labor required to wire the MCC would be less.

The engineering and design time is the same as in Alternative 1, or possibly less. If the MCC factory provided I/O lists, the time spent in documentation would be reduced slightly. The cost of installation and wiring at the plant is significantly less since the only control wiring required is the PLC communication cable. The time required to commission the MCC is also less since the PLC rack and their connections to the starters are tested at the factory.

C. Alternative 3

The final scenario is a MCC with all DeviceNet starters as is actually installed. The base cost for the MCC structures, starters, etc. is the same as the previous alternatives. There is an incremental material cost over the other two alternatives, which includes the DeviceNet communication modules and the required connectors, which are installed and tested at the MCC factory.

The installation of a DeviceNet MCC is almost identical to Alternative 2. The only on-site control wiring required is
running a DeviceNet cable from the scanner card to the MCC. Start up cost is also lower since much of the hardware has already been tested at the factory. Table VIII below provides a summary of the overall installed cost comparison for all three alternatives.

Initially, the engineering and design for a DeviceNet MCC may be much higher than a traditional PLC system. New CAD templates have to be generated and there is a learning curve in working with DeviceNet software and hardware. However, after a few DeviceNet projects, the overall design time and costs would be less than a PLC system. There are far fewer wires to document and keep track of.

<p>| TABLE VIII |</p>
<table>
<thead>
<tr>
<th>Cost breakdown of starters wired to a PLC rack versus DeviceNet.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>MCC Base Cost</td>
</tr>
<tr>
<td>PLC I/O Hardware Cost</td>
</tr>
<tr>
<td>DeviceNet Hardware Cost</td>
</tr>
<tr>
<td>Labor Cost at MCC Factory</td>
</tr>
<tr>
<td>Engineering &amp; Design Cost ($60/hr)</td>
</tr>
<tr>
<td>Installation &amp; Wiring Cost (on-site, $60/hr)</td>
</tr>
<tr>
<td>Start-Up Cost ($60/hr)</td>
</tr>
<tr>
<td>Total Installed Cost for the MCC</td>
</tr>
</tbody>
</table>

**D. Distributed I/O Costs**

In Alternative 3, we see that the cost of DeviceNet MCC was less than installing a traditional PLC control system. The higher cost of the DeviceNet hardware is offset by the lower labor costs. In most cases this also applies to the case of DeviceNet field sensors and I/O wired to DeviceNet modules. However, unlike the case of MCC control wiring, sensor and field I/O wiring requirements can vary substantially. Variables such as a I/O density or environmental requirements (indoor versus outdoor) can affect whether the overall install cost of DeviceNet is less than conventional PLC I/O.

In general, DeviceNet field I/O is cost effective in cases where concentrated groups of I/O are located over a large geographic area. Instead of placing several PLC racks in the field, the size of DeviceNet modules allow for more flexibility in distributing I/O. In such cases, long conduit runs can be avoided, reducing costs.

**V. LONG-TERM BENEFITS**

The hidden cost benefits of DeviceNet versus conventional PLC I/O come from the additional data that DeviceNet modules provide. In a system where the DeviceNet data is effectively integrated into the PLC and HMI systems, the information can help increase productivity and reduce downtime. Assuming the initial installed cost was equal for a DeviceNet versus a conventional PLC system, the overhead costs for all of the additional available data is zero. This being the case, effective use of the available data becomes an important issue. Below is a brief overview describing how the DeviceNet data is being used at the Springfield mill.

**A. Starter Data Integration**

In the case of DeviceNet starters, the additional data has helped reduce the time it takes to start the raw materials handling system from a maintenance down period. In the past, open breakers or starters left in “hand” mode have contributed to slow start-ups. Also, if a motor stops running, the operator and maintenance personnel have more data to quickly determine the problem.

The operators interact with each network motor starter through a graphical process overview screen on their HMI screens. Green indicates the equipment is running and red indicates that the equipment has stopped. If a starter senses a problem such as over current or phase imbalance, the “Starter Warning” bit will be set and the motor display will turn yellow.

By clicking on a piece of equipment, a window pops up on the HMI screen as shown below in Figure III. The equipment number and description is displayed as well as the status of that motor. From this window, the operator can start or stop this motor.

**FIGURE III**

HMI window to start and stop a motor.

In this case, the motor R-435-XZ is running in automatic (as opposed to running in hand). The “Motor Warning” display indicates that the starter is sensing a problem. The graphic symbol on the process overview display would be in yellow for R-435-XZ.

For more information about the “Motor Warning” on this equipment, the operator or maintenance person can click on the “Starter Data” button to bring up details. The following window, shown in Figure IV below, will pop up on the HMI, providing more details about this particular starter.
Along the top of this window is some information about the DeviceNet network and the node number of the starter. The left side displays the state of the various discrete status bits and their corresponding PLC program addresses. The three analog values from the starter are also displayed on the right side. Just below the analog displays is a graphical display of how the data from the starter is mapped into the PLC integer file.

With this information, the operations and maintenance team can work towards resolving the root cause of the problem. In the case of R-435-XZ, we can see that the “Thermal Capacity” and “Average Current” is higher than normal. An orderly shutdown of the process can then begin to allow the maintenance team to remedy the problem. Once the issues are resolved, the operators can quickly bring the system back on-line. Without access to this diagnostic information through the DeviceNet starters, if this starter had tripped in an overload condition, the process would have been down for a far longer period because the raw material would have plugged up the equipment.

The DeviceNet starters also provide information as to why a motor will not start. In the case of R-210-K, either the breaker has been turned off, or the starter has tripped. In this particular implementation, a breaker open condition and a faulted or tripped starter cannot be differentiated. However, this has not been a major problem since either condition requires an electrician to check out the equipment.

### B. Bearing Monitor Integration

Bearing data is also available through the HMI for real-time monitoring and alarming as shown in Figure VI below.

By clicking on the equipment on the process overview page, the operator or maintenance person can display information about a particular bearing. If a bearing is overheating or is sensing excessive vibration, an alarm will display on the HMI. The operator can investigate the alarm with a maintenance person to determine the problem. This can avoid a catastrophic failure resulting in substantial downtime to replace a bearing. The PLC is also programmed to shutdown if the bearing is outside operating limits. This can be very important in minimizing fires resulting from overheated bearings.

Long-term trend charts are available on the critical bearings as well. Studying these trends can point out possible bearing failures and can be changed out on the next scheduled maintenance period.

### VI. ISSUES AND OPPORTUNITIES

Like any new technology, there is a learning curve associated with designing and starting up a DeviceNet system. Most of this is in learning the software to configure the scanner card and determining how the PLC communicates with the scanner card. Configuring the various modules to properly communicate with the scanner card may also take some time as well. However, for someone who is familiar with the software and hardware, the time required to design and start up a DeviceNet system is comparable to a standard PLC system.

The sheer size of a larger DeviceNet system can take time to debug. In a traditional I/O system, there may only be half a dozen racks. Stated another way, this would represent a PLC with a network of 6 racks. With DeviceNet, the network may range in the hundreds of nodes. Setting up each of the nodes and programming the scanner card can take some time.

Troubleshooting DeviceNet is easier than in a traditional I/O system in one respect. The scanner cards can provide diagnostic information to quickly determine the cause of the problem. Figure VII below shows some of the diagnostic...
screens based on the status words from the scanner cards. The information displayed on the scanner cards can be viewed from any HMI station, saving the electrician or engineer a long walk to the PLC cabinet.

FIGURE VII
DeviceNet diagnostic screen

Clicking on any of the cards brings up a screen which provides more detail on the nodes that have failed. The type of failure (device failure, communication failure, media issue, configuration problem, scanner problem, or power failure) can also be displayed.

In a well-designed network, the failure of a few nodes will not affect the entire system. Changing out a defective node can be done while the process is running. However, since DeviceNet is a network based system, troubleshooting anomalies is much more difficult. Tools such as oscilloscopes and diagnostic software become a necessity. Unfortunately, this may mean that a technician or engineer that is well-versed in DeviceNet protocol may be required to resolve some issues.

At the Springfield plant, the most common issues have been:

1. DeviceNet modules that have failed. The remedy is to simply replace the module. Typically, all that is required is to set the node address in the new module and replace the module. This can be performed while the rest of the process is running.

2. Issues with the DeviceNet media. Water in conduit seems to be at the root of some failures. Drying out the wires and sealing the suspected conduit usually resolves this issue.

3. Electrical interference. In some networks, this seems to be a nagging problem. It’s quite possible that Variable Frequency Drives or other sources of noise have affected some networks.

4. Finding ground loops. Some of the networks had a problem of dropping out unexpectedly. Ensuring the ground wire was not touching the surrounding conduit seemed to cure this problem.

5. Training. As with any new system, training the maintenance team is a continuous process. With DeviceNet, much of the troubleshooting has become computer based. Even changing out a node requires the use of a computer to set the address. Although it is a relatively simple task, training is required on the software and hardware.

Although a tremendous amount of data became available with DeviceNet, it is of no use unless it can be presented to the operations and maintenance personnel in a user friendly format. Current opportunities lie mainly in integrating the large amounts of data into the PLC and HMI systems, including:

- Completing work to interlock excessive current, thermal capacity, and phase imbalance.
- Alarming starter problems in HMI.
- Alarming bearing problems in HMI.

Opportunities also exist in storing critical starter and bearing monitor data in an industrial database. Such long-term analysis would be important for preventative maintenance and identifying process upsets.

VII. CONCLUSION

Currently, the most common control system involves a conventional PLC or DCS with the field devices hard-wired into I/O racks. Such a system often means that more physical I/O space is required to gather more data from the field, increasing installation costs. Implementing an open distributed control system such as DeviceNet is a viable alternative to the conventional approach, allowing access to large amounts of process data without additional wiring or incremental I/O overhead costs.