Title: **Intelligent Motor Control Centers~~Smart~~ (IMCCs) – The Present and the Future ~~A New Concept in Integrated, Intelligent Motor Control Center Technology~~**

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Areas of Interest

Application of fully integrated, low-~~-~~voltage motor control equipment, open device-~~-~~level control networks, and software monitoring package to make preventive maintenance possible in the manufacturing process.

Abstract

Device-~~-~~level integration through digital communication i~~hold~~s the key to unlocking the full potential in the electronic controls being installed in industrial plants today. Users in all industries are seeking solutions that integrate software, hardware and communication technologies to deliver plant-floor benefits such as improved process control and diagnostics and increased reliability.~~-~~ The ~~packaging and~~ development~~ing~~ and packaging of new technologies in device-~~-~~level communication and sensing capabilities, along with dedicated software, enable~~provide for~~ intelligent control architectures to ~~hat control and~~ provide both abundant real-time process information ~~aboutfor the process~~, as well as predictive maintenance information to further improve productivity.

~~and can also predict maintenance needs to improveprograms that maintain productivity.~~

Background

~~In~~ Historically, m~~M~~otor c~~C~~ontrol c~~C~~enters (MCCs) ~~used~~ in the process industry have ~~incorporated~~used~~, there was first~~ hard-wire interwiring for control and monitoring of ON/OFF status, and the MCCs ~~s,of controllers and~~ sometimes included transducers for process monitoring feedback ~~of process monitoring~~. Advances in~~cluded~~ intelligent power components have led to ~~PLC controllers with additional feedback monitors. Consequently, there was~~ a trend in recent years to include automation products such as AC drives, soft starters, electronic overload relays, and digital power monitors within traditional MCC~~motor control center~~s. ~~Th~~Integrating these intelligent devices~~is~~ has~~s~~ g~~a~~iven rise~~birth~~ to a new breed of MCC, often called the Intelligent Motor Control Center (IMCC). While called intelligent, these MCCs~~However,~~ still ~~what was~~ lacked~~ing has been~~~~was~~ ~~an integrated intelligent~~ integration of the controllers, field sensors, and ~~the~~ software linking the whole process together. In addition, there has been~~was~~ a need for ~~additional~~integrated software to analyze and provide a monitoring system for predicting maintenance needs and driving other necessary strateg~~y~~ies to improve the system reliability~~y of the system~~.

Increasing Process Uptime with Predictive Maintenance Solutions

The goal in any continuous ~~the~~ process is to keep it running efficiently and productively. This ~~which~~ requires monitoring the operation as well as including the proper maintenance. Accordingly, o~~O~~perations personnel must~~should~~ migrate from a preventive maintenance culture to a predictive maintenance culture. Fundamental to~~The basis for~~ a predictive maintenance program is integrating~~that~~ sensors ~~can be put in place~~ to provide critical actuator or motor health data ~~regarding the actuator or motor health~~. -This level of communication can provide operators ~~with~~ a continuous stream of performance ~~data~~ or change-of-state data, reflecting ~~due to~~ any degradation of the sensor or attached system and ~~that will~~ alerting operators of the~~pending~~ need for maintenance. ~~An e~~Effective predictive maintenance will leverage this data so that electronic sensors and controls can be left in place longer compared to~~than under~~ a preventive maintenance structure~~regime~~.

The potential savings with predictive maintenance solutions are twofold. First, ~~. The first is that~~ the device can be left in place beyond the calculated statistical replacement scheduled under a preventive maintenance program. Second~~ly~~, since devices are replaced less frequently, the failure experience due to infant~~infant~~ mortality and misconnection is~~are~~ reduced. This is shown graphically in F~~f~~igure 1.

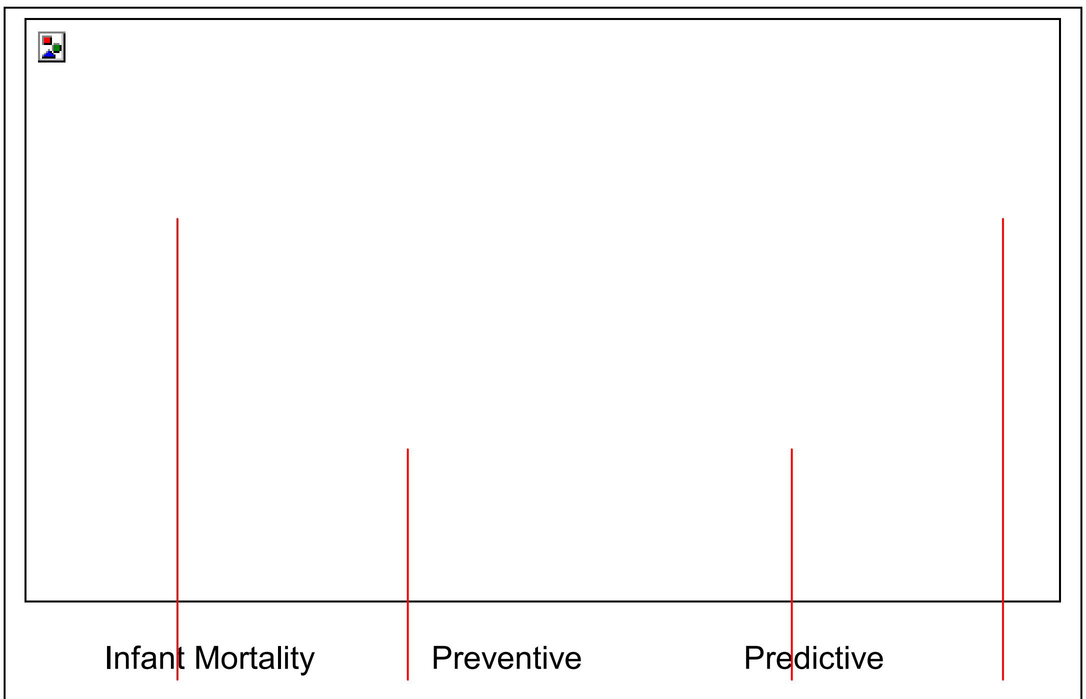

Figure 1

This paper focuses on the three major components that are integrated in an IMCC, and specifically on device-~~-~~level communication within an IMCC and discusses the potential to~~for~~ use ~~of~~ the information in~~to~~ an effective predictive maintenance program.

The three major components of an IMCC ~~are:~~

include

t~~A truly integrated~~n ~~IMCC involves~~~~comprises of five major components:~~

~~□ T~~he MCC structure with built-in communication media, ~~a~~

~~□~~ i~~I~~ntelligent motor control components and ~~s~~

IMCC monitoring software and documentation.

~~Communication networks~~

~~□IMCC mMonitoring software~~

~~□IMCC systems software and electronic documentation~~

The goal of ~~the integration of~~integrating these components~~With~~~~hen these elements are integrated as a system,~~ is to make the IMCC easy to install and maintain without specific training or local expertise.- ~~affords~~ When ~~put together~~assembled as a system, the IMCC -would provide~~afford a~~ ~~"~~plug-and-~~&~~ play~~"~~ set-up and monitoring of ~~via dynamically configured screens showing~~ real-time data, as well as ~~,~~ trending, component history, wiring diagrams, user manuals~~,~~ and spare parts information~~are~~ ~~at the touch of a button~~.

-This integrated ~~An~~ IMCC ~~would~~ minimizes facility downtime by quickly providing answers to questions like:

- How is the process performing?
- What tripped, and why did it trip?
- Has this problem happened before? When? Why?
- What parts are needed to fix the problem?
- Is anything else about to trip? How soon?

~~Is anything else about to trip? How soon?~~

~~What tripped, and why did it trip?~~

~~-Has this problem happened before? When? Why?~~

~~-What parts are needed to fix the problem?~~

- Where's the circuit diagram? The users' manual?
- Do we have any spare units?

Given this potential for easy access to useful process information, the technology inside the IMCC has now become the most important~~driving~~ purchasing criterion~~criteria~~ when users~~for~~ select an~~ion of the~~ MCC vendor.~~is becoming more important than the hardware design of the MCC.~~ M~~That is, m~~any ~~user~~ MCC-user specifications now ~~s are~~ focus~~ing~~ on ~~the~~ solid-~~-~~state overload relays and communication networks ~~more than, for example,~~over previously highly requested criteria, such as the design of power bus bar connections.

The Three Integrated Technologies of the IMCC

The effectiveness of an IMCC for predictive~~motor~~ maintenance relies~~hinges~~~~is predicated~~ on three technologies~~,~~ which allow~~afford~~ integrated intelligence and simple operation, and allay concerns about device-level networking, configuration and maintenance:

I. ~~:~~

A transportable s~~S~~oftware m~~M~~onitoring and documentation package;~~ that can be transported~~

II. Network-ready, solid~~-~~-state motor controls and motor protectors; and

III. Integrati~~ng~~on of an open device~~-~~-level network into the IMCC.

I. Transportable SsSoftware Mmonitoring Ppackage ~~that can be transported~~

~~Via readily available operator interface software,~~ Uusers today already have the *potential* to monitor data and establish predictive maintenance practices with readily available operator interface software. The reality, however, is that users seldom take the time to create customized screens for this purpose. Predictive information is still an untapped resource in most facilities. Some users do not see the cost justified by perceived benefits, other users are solely focused on maintaining and improving the basic process control and others are concerned that the data collection might negatively impact control speed. ~~Whether because the cost doesn't justify the perceived benefit, because the focus is maintaining and improving the basic process control, or because of concerns about data collection impacting control speed, predictive information is an untapped resource in most facilities.~~

A solution to ~~this dilemma~~the challenge of monitoring data is a *transportable* software monitoring package: ~~– that is,~~ a package with pre-configured screens that can be used in conjunction with any IMCC. This approach would allow users to easily view IMCC information without creating any customized screens. ~~The IMCC monitoring software would present comprehensive system information in a pre-configured set of reports by merging~~ I~~information that~~ntelligent -devices would be polled by the software, their device type recognized (e.g.:~~i.e. ,~~ ~~FVNR~~full-voltage non-reversing starter (FVNR), AC dDrive, sSolid-s-State mMotor cController, etc.) and a pre-configured screen would display the most critical real-time parameters. ~~are feeding through the communication network and~~ The polling algorithm could segregate the monitoring and control, enassuring that monitoring scans do not affect control scans. By supplementing this information with a database containing ~~a pre-loaded database within the software containing~~ job-specific ~~project~~ information (AutoCAD documentation, spare parts lists, nameplate information, etc.), comprehensive system information for preventing and minimizing downtime would be at the users' fingertips.

For example, in the event of a problem, operators in the control room~~upon energizing the MCC,~~ might want to see an overview of the IMCC, to determine~~see~~ which unit is issuing a "warning" signal, and ~~what the cause is~~the problem's cause. Such information could allow the user to correct a problem before unscheduled downtime occurs. This could be accomplished via a screen ~~the monitoring software~~ that mimics the ~~would display an~~ elevation view of ~~mimicking~~ the IMCC, complete with nameplates and "pilot lights" on each "door" to show status, including (Oon/,Ooff, warning, tripped and, communication failure) ~~in the control room~~ . ~~As shown~~(see ~~in~~ Ffigure 1.).

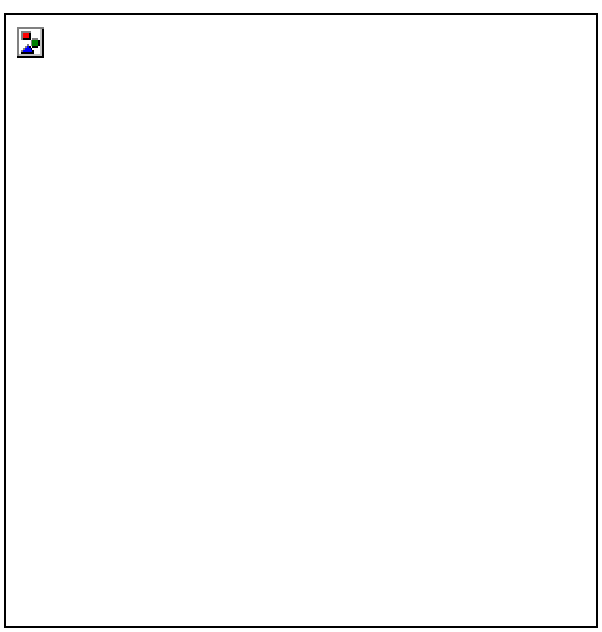

Figure 1

Alternatively,~~ely~~ presentation of monitored data~~it~~ could be accomplished by a "spreadsheet view,"~~",~~ allowing maximum information on a single screen, as well as filtering and sorting of data.

To probe further, users might want to
~~The software application coexists alongside operator interface and product-specific software (such as drive or power demand monitoring software) and automatically compiles key information about the MCC and all of its components.~~

~~Additional functionality of the Monitoring IMCC software:~~
~~*Living MCC elevation view* – This screen replicates the actual MCC line-up, complete with nameplates and "pilot lights" on each "door" to show status (on, off, warning, tripped, communication failure) so users can identify problems at a glance. [See photo for details.]~~
~~*Graphical view of each unit* – A screen is designed for each family of products (Soft Starters, Drives, Smart Motor Protector, etc.) so users can~~ quickly see key data, such as amperes, time-to-trip, trip cause, ground fault amperes, and I/O status pertaining to a specific MCC unit. In this instance, c~~Here c~~are must be taken in the development of the user interface to provide useful information rather than an overload~~just mountains~~ of data. For example, today's AC drives ~~typically~~can haves more than~~over~~ 300 parameters, but only a dozen are typically viewed during operation!

A solution to help users wade through the information overload would be to provide pre-configured screens showing the parameters typically of greatest interest~~,~~ while allowing users to re-define the parameters to be displayed. Ideally, the user also should~~ also~~ be able to display critical parameters via trending graphs and large "analog" dials for greater emphasis. An example of such as screen is shown in Figure-2. Electronic Data Sheets (EDSs) – described in the next section – a~~A~~lso could be available to the maintenance personnel over the network ~~are the Electronic Data Sheets (EDSs will be described in the next section~~of~~) of~~ any connected devices, which could be used to establish which process variables to monitor on a continuous basis.

Figure 2

~~Each screen is pre-configured to show the parameters typically of greatest interest, while allowing users to easily re-define the parameters to be displayed. Trending graphs and analog dials are featured on most screens. [See photo for details.]~~

In addition, operators will have the opportunity to track historical data for a specific motor. ~~, s~~S~~T~~~~ometimes t~~his information can be a critical clue ~~holds the~~ when~~key to~~ identifying the source of downtime. Historical tracking can answer the following questions:

- Is a trip occurring every Sunday at 5:00 p.m.?
- Has this problem happened before? How was it fixed? Who fixed it?
- Was anything changed recently? The trip setting? The contacts?

If a trip does occur, the software ~~could~~ also could serve as a comprehensive information system, minimizing downtime by providing information beyond real-time data. For example, to~~Spreadsheet view – Ideal for displaying maximum information on a single screen, the data can be filtered and sorted to meet unique user needs.~~
~~Spare parts lists – For~~ help quickly identify~~ing~~ which replacement parts need to be ordered~~s~~, the software could provide a list of electrical components contained in~~is provided for~~ each unit.
~~MCC documentation –~~ Another common source of excessive downtime and frustration is lost documentation. The software could ~~To eliminate time spent searching for documentation, users can view~~ contain unit wiring diagrams, user manuals~~,~~ and as-built AutoCAD documentation.

~~H~~~~MCC h~~~~istory sometimes holds the key to identifying the source of downtime.~~
~~Is a trip occurring every Sunday at 5:00p.m.?~~
~~Has this problem happened before? How was it fixed? Who fixed it?~~
~~Was anything changed recently? The trip setting? The contacts?~~
~~These events could be tracked within the The software, and offer great insight to the maintenance person. can track the history of each unit and structure (such as replacing contacts or changing the overload trip setting).~~

To further aid as a~~facilitate~~ commissioning and troubleshooting tool, the software ~~could~~ also could be capable of initiating~~includes~~ limited control ~~capabilities~~, allowing the software to take control away from the programmable logic controller (PLC)~~PLC~~. A~~with a~~ security barrier would be necessary to ~~to~~ prevent unauthorized access to these control functions.

The software polls the Device Network, searching for devices declare themselves to be located in MCCs. Concurrently, the unique Device Network identification number is obtained from each device, allowing the software to pair each device with information contained in the user's specific data file. This information includes nameplates, unit details, wiring diagrams, manuals, spare parts, and other details. The data from the device, together with the user specific data, is used to automatically generate the user interface screens.

With the trend toward locating MCCs in low-traffic areas, clearly the software must be viewable remotely, i – ideallyThe MCC monitoring software can reside in a control room or, at an engineer's desk i—in addition to being viewable via a laptop plugged into the IMCC... This means the software must be viewable over facility-wide networks such as Ethernet, as well as on the supervisory control networks such as ControlNet, and/or at the -device--level networks such as DeviceNet.. This ability to bridge device--level data across all levels of a plant is a key consideration when installing a new control system that device level data can be bridge across all level of a plant , or on a laptop used by maintenance personnel that is connected to the plant process control network. To minimize the network bandwidth consumed, data is gathered for "active" screens (those currently being viewed). Second, the polling algorithm segregates the monitoring and control, assuring that monitoring scans do not affect control scans..

Note that the software would not be intended to augment supervisory graphic software and coexist on the same Windows NTto replace operator interface software along withor product-specific software, (such as drive or power--demand monitoring software)., as those packages are already optimized for fundamentally different tasks such as control and product configuration.

II. Network-Rready,, compact Ssolid- Sstate Mmotor Ccontrols and Mmotor Pprotectors

The information available to the IMCC software and to a predictive maintenance program is dependent upon the use of the the raw data produced by intelligent devices in the MCC and associated system.

The design of the supervisory and connected device networks must permit timely receipt of alarms produced by end devices and the interrogation of the selected device Eelectronic Ddata Ssheet (EDS). The concept that sensors and actuators produce data and is the major shift from our past models that will fuel the predictive maintenance program. Figure 3 is an example of a device network "WHO" screen which graphically shows devices connected.

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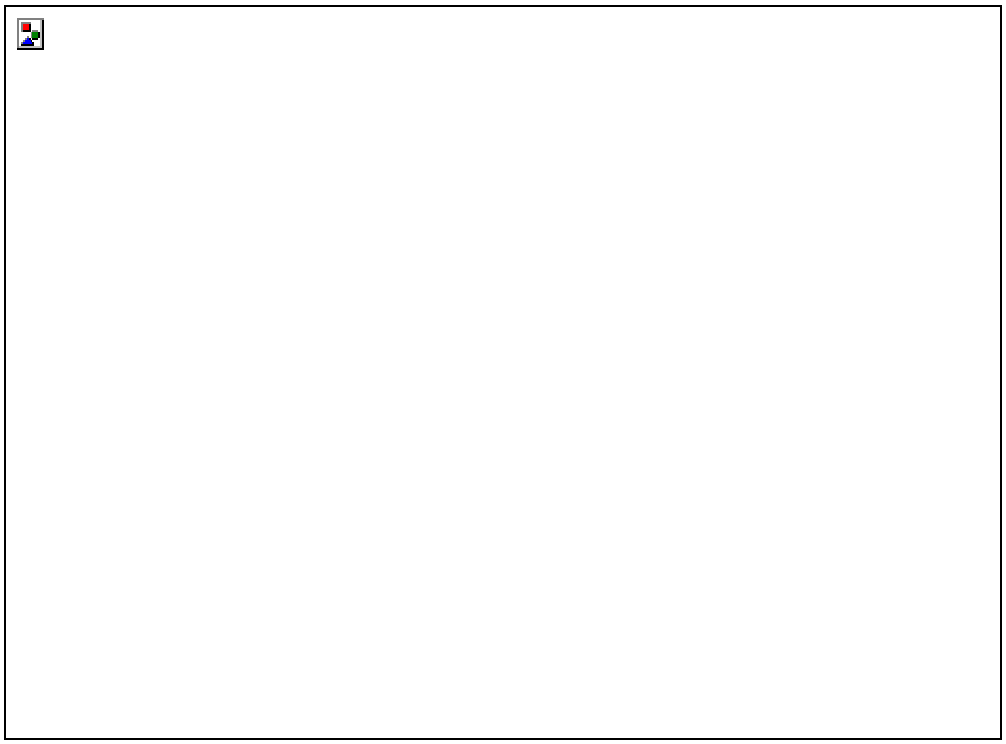


Figure 3

Beyond the graphically showing the health of the network, the "WHO" screen will permit to easily the user to easily navigate and select any connected device object. The Electronic Data SheetEDS of the selected object can thean bebe displayed with current operatoringoperating parameters. As mentioned in the previous section, this is meant to augment the capability of the IMCC monitoring software. An example of a Smart Overload EDS is shown in Figure 4 other devices and their associated EDS are shown in Appendix A.

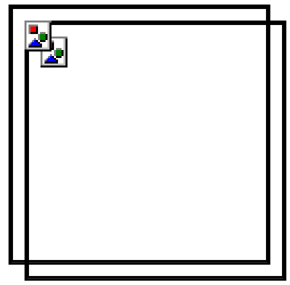


Figure 4
Smart Overload EDS

-Since t~~T~~he most common device in the MCC is the motor starter, ~~so the~~ intelligence within~~of~~ the starter is paramount. Over the past few years, a number of solid~~-~~-state technologies have been introduced into the motor starter. Early versions performed basic overload protection but added an adjustable trip and quicker phase-loss protection. These devices proved to be very popular because of their comparable cost to traditional overload relays. Later, overload relays added protection such as jam, stall, ground fault~~,~~ and phase imbalance. More recently, overload relays began incorporating communication capability. These overload relays allowed the user to monitor current, percent thermal capacity utilized~~,~~ and identify the reason for a trip. Still, these devices were not true network-driven products~~,~~ as only a few parameters were adjustable, parameters couldn't be changed over the network~~,~~ and communication required an external module. Furthermore, the cost of this overload technology often limited its application to large or critical motors.

Overload relay~~Today~~ t~~T~~echnology has evolved. Today, ~~to where~~ networked solid-state overload protection can be provided cost-effectively ~~be provided~~ on *all* loads throughout the plant, ~~and~~ not just on critical loads. With features such as built-in communication, ~~built-in input points,~~ programmable alarm and trip values, and ~~patented~~ ground~~-~~-fault sensing technology, users now have unprecedented information and control capability to:

- Correct situations generating "warning" alarms before anything trips – such as a jammed conveyor or clogged filter;
- Identify how soon a motor will trip (in minutes and seconds), helping identify the urgency;
- Log events to determine patterns; ~~(Is the motor always tripping Sunday at 5:00 p.m.?)~~
- Identify the cause of the trip from the control room, giving maintenance personnel a starting point;

- Coordinate ground-~~-~~fault protection, so an individual load trips rather than a whole MCC line-up;
- Pinpoint the source of grounding problems to individual circuits; and
- Monitor the current draw on each load to check for process problems;

These overload relays may even include built-in input points~~ as well~~. ~~Why?~~ Frequently, users need input points in units to monitor the status of the disconnect switch, contactor, or hand-off-auto switch. For these situations in the past, users ~~traditionally have~~ had to either wire to an input/output (I/O) chassis or add a small I/O module in each unit. Adding I/O to the overload relay – ~~(~~and to communication modules associated with AC drives and solid-~~-~~state controllers –~~)~~ ~~Today's technology, such as the solid state overload relays and communication modules address this issue by incorporating I/O points that can be relayed to the control network. This virtually~~ eliminates hard~~-~~wiring to the I/O ~~-~~chassis~~ further increasing the reliability of the system~~, allowing all control and monitoring to occur over the network.~~rk.~~

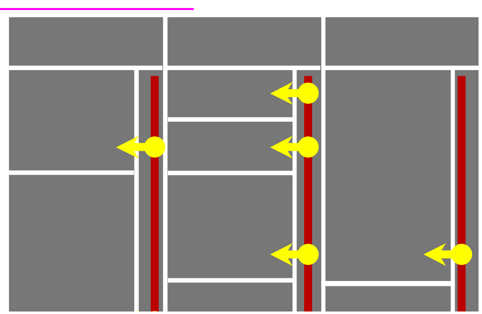
III. Integration of an Open Device-Level Network in the MC~~C~~

~~**Built-In DeviceNet Provides Users Many Benefits**~~

A significant number of users have now successfully implemented device-level networks in MCCs. The r~~R~~easons for implementing this technology, in lieu of traditional hardwiring to an I/O chassis, include~~d~~ access to more information, simplified interwiring and ~~, simplified~~ documentation, and ease of adding or ~~/~~moving units.

Various physical media approaches have been implemented, with the most common ~~The traditional method of wiring a Device Network within an MCC~~ consisting~~ed~~ of ~~routing~~ a~~the~~ trunk line in the horizontal wireway~~,~~ and ~~extending~~ "daisy chain" drop lines in the vertical wireways. The ~~DeviceNet~~ cable has generally been round, and rated 4 amperes, 300 volts, NEC/CEC Class 2. Connectors between the trunk line and drop lines have either been terminal block style or quick-connect style. This media approach seemed~~While~~ logical during initial implementation of device-level networks, but as networks in MCCs become mainstream, special tooling and improved designs can be justified to improve reliability, usability, and cost of each of these physical media elements. ~~The new built-in DeviceNet concept improves on each of these aspects, while lowering installed cost.~~

To improve reliability of the cabling system, trunk and drop cables could be placed behind barriers, rather than remaining exposed in the MCC wireways. This would minimize the danger of accidental damage to the communication cable when large power cables are pulled through the wireways. (Figure 5)~~The trunk line and drop lines are routed behind barriers, rather than within the MCC wireways. This isolates the primary DeviceNet cables from mechanical damage which may have otherwise occurred when pulling power cables through the wireways.~~



T~~Also t~~o~~To~~ improve reliability and increase flexibility of the cabling system, the “daisy chain” architecture also could be enhanced. Shortcomings of the “daisy chain” architecture are twofold: the chain can accidentally be broken and equipment unintentionally shut down and~~, plus~~ adding a device requires shutting down an adjacent unit. One solution is to provide ~~Six Device~~ n~~N~~etwork ports at~~are provided in~~ the rear of each vertical wireway~~.~~ (Figure 6). This approach ~~,~~ allows the trunk and drop lines to remain safely behind barriers, while simplifying installation, relocation, and adding of MCC units. Users would simply plug in the unit, and then plug in the communication~~DeviceNet~~ cable.

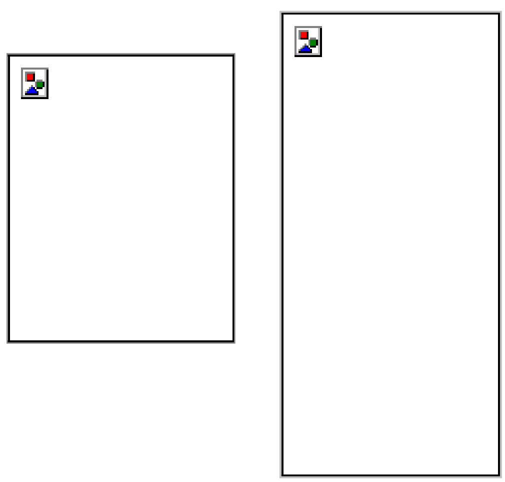


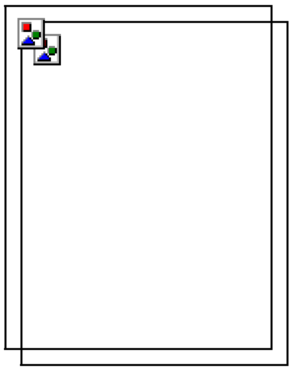
Figure 6

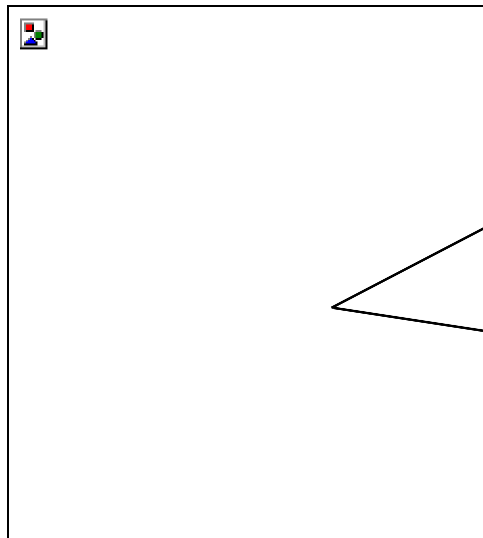
~~The design also eliminates shortcomings of the "daisy chain" architecture, namely the danger of the chain being accidentally broken and equipment unintentionally shut down, as well as the need to shut down an adjacent unit when adding a new unit to the chain.~~ To simplify system design and lower cost, several new cables offer advantages over t~~The trunk line is routed in the *center* of the MCC, minimizing the length of the drop cables – a criteria which can restrict use of the maximum 500kBaud communication rate.~~
he traditional 4A round cable. Communication c~~The cable used for the trunk line and drop lines is *flat* cable rated 8 amperes, 600 volts, Class 1.~~ables ~~The increased ra~~rated~~ting of~~ 8A are now available. When~~,~~ combined with an~~ new~~ 8A ~~DeviceNet tested~~ power supply unit, this eliminates the nuisance and cost of providing multiple power supplies in most MCC line-ups. Flat cables also are ~~now~~ available. This~~The choice of flat cable~~ enables use of insulation displacement connectors (connectors that clamp onto the cable, piercing through the insulation jacket), minimizing breaks and splices in the trunk and drop lines. The flat cable also slashes manufacturing time because a ~~DeviceNet~~ wire stripper allows the cable to be stripped in a single motion. Finally, cables with ~~The~~ Class 1 insulation ratings are now available, eliminating~~es~~ the requirement for separation from power cables.

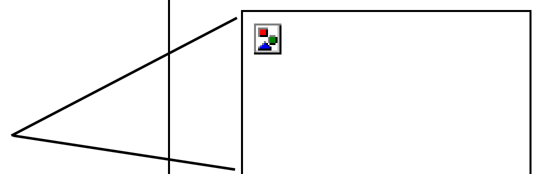
Conclusion

The ~~maturing and~~ integration of the three maturing technologies discussed in this paper~~,~~ - software, control hardware, and communication - has given the IMCC the potential to offer significant benefits for large industry processes such as cement manufacturing. The optimization of cost and function of the IMCC components has yielded ~~Today's IMCC users should expect much more than just intelligent hardware stuffed inside their MCC. They should expect~~ a plug-and-~~-~~play solution that will offer savings during design, start-up and operation which will quickly exceed the higher acquisition cost of the smart components. ~~, involving fully integrated hardware, software, and communication.~~ The end result is a motor control scheme that configures easily, ~~The end result being a more reliable, lower cost design that~~ starts up smoothly and provides highly useful information to predict maintenance, improve productivity, and maximize uptime.

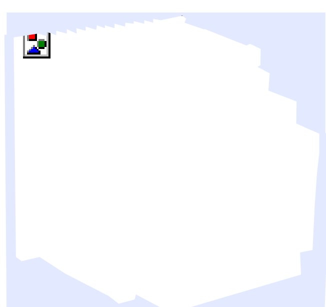
Appendix A

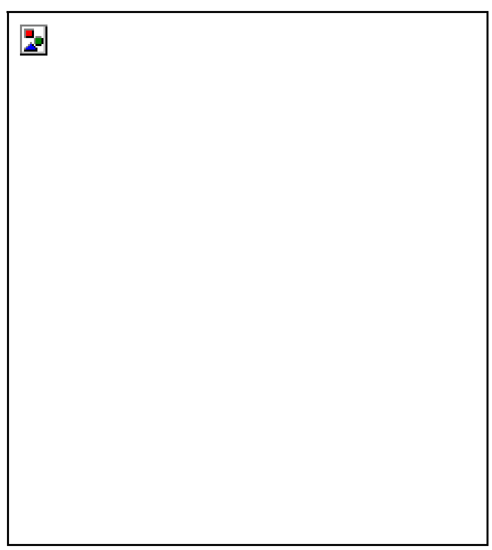




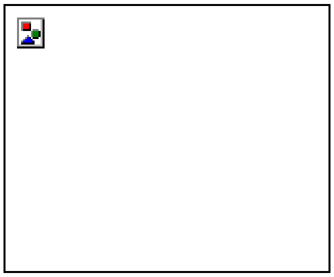


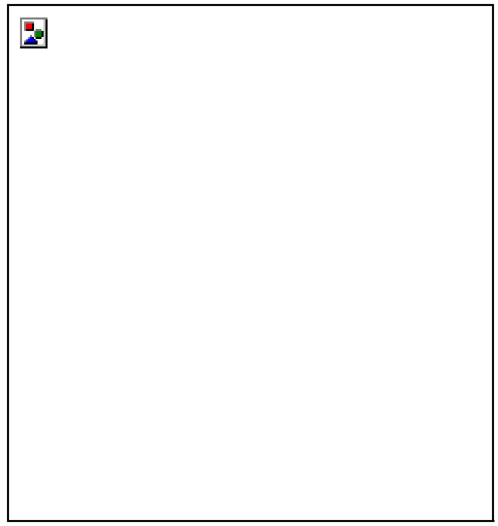
Adjustable Frequency Drive EDS



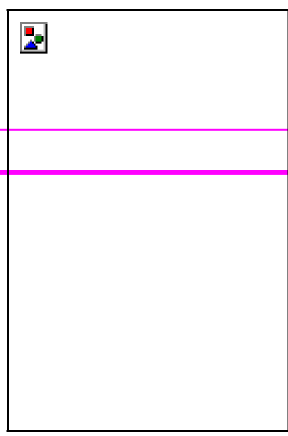


Soft Starter EDS





Smart Bearing EDS



Device Network port

4 input points

Ideal for monitoring contactor status, disconnect switch, overload trip and Hand-Off-Auto switch

2 output points

Direct control of motor starter coils up to NEMA size 5

DeviceNet Starter Auxiliary (DSA)

DeviceNet Starter Auxiliary