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Making Better Decisions on the Plant Floor Using SCADA Systems

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Abstract
With the printed circuit board becoming increasingly complex, there is an ever-growing need to implement manufacturing standards that ensure high productivity at even higher yields. Factors such as operator error and incorrect data collection make producing such boards an exercise in frustration. If a company is going to be successful in the future, it must look to implement a total system of **S**upervisory **C**ontrol **A**nd **D**ata **A**cquisition as a means of success. Since this industry is one of the last high-tech industries to embrace **SCADA**, this paper will give attendees a better understanding of why such a discipline is a necessity.

Introduction
SCADA systems have redesigned the landscape of America. Water Districts store resources in grids, not reservoirs. Electrical Utilities serve millions of customers. Oil Companies now have thousands of miles of unmanned pipelines thanks to SCADA. Today, four technologies open the door for manufacturers: (1) Spread Spectrum, (2) TCP/IP, (3) Ethernet, and (4) Internet.

Spread Spectrum
The FCC requires special permits for radio signals longer than 100 milliseconds. Spread Spectrum splits the signal using code division multiple access, (CDMA) into packets less than 100 MSEC of time; and transmits them at different frequencies.

Therefore, no FCC permit is required, each Spread Spectrum uses a unique "Seed" (DIP switch setting), and cross-over collision is minimal. This technology is now used in cordless phones, and in industrial settings. The cost of Spread Spectrum is a fraction of the cost of wiring.

TCP/IP
TCP/IP is now THE communication protocol. Programmable Logic Controllers (PLC), recorders, and process analyzers have TCP/IP embedded in their Firmware. The INTERNET holds the ultimate promise for SCADA application. This translates into low-cost hardware, and therefore, an attractive solution for industry.

Ethernet
Ethernet popularity has exploded! PLC manufacturers routinely use Ethernet modules with their PLC.

Quiescence
Communication bandwidth vs. traffic dictates the volume of information; therefore, SCADA systems use Quiescence as a design strategy. No change in status deserves any transmission of information. When the system is "quiet" the transmission is OFF. When field values change, then information is transmitted. When a major "Event" occurs, the SCADA system falls back to a pre-established emergency condition.

Communication Media
- Copper Wire (twisted pair)
- Telephone Lines
- RS-232C, RS-422, RS-485
- Special Wire (Device Net)
- Ethernet 10-base-T
- Fiber Optic (i.e. FDDI)
- Spread Spectrum

What Drives SCADA
SCADA begins with a sensor linked to a communication media connected to a computer. SCADA systems can be as small as one sensor, or as large as 30,000 sensors (and outputs).

Implementation Set Up
A clear selecting of objectives is the smartest way to save costs. On the other hand, frugal construction invites noise into the system; too much data and not enough information. The design objective must be the combined effort of management, engineering, production, and accounting. If the engineering department designs a "perfect" SCADA system without the input of production, the system is doomed to failure.

Objectives
- SPC—Statistical Process Control
- Line Clearance
- Material Scheduling
- Temperature Control
- Humidity Control
- UV Light Control

Statistical Process Control (SPC)
Statistical Process Control and SCADA are natural blends. SCADA collects data, and SPC shows the data. X-bar and R charts, PARETO Curves, and standard deviation are perfect fits for SCADA. X-bar charts show the process in relation to Sigma

deviations, and they work hand-in-hand with range charts that show the intensity of those deviations. X-bar and R charts are best used on-line to show the production supervisor when problems are about to happen.

PARETO
Curves show the mistakes in the process and help to set the priorities on correcting deviations. PARETO can be daily or weekly. SCADA is not good at finding PARETO problems because of the cost of sensors. However, if the machine has built-in diagnostics then SCADA is great.

Standard Deviation
A small standard deviation (SD) relates to a tight process, and a large SD relates to an out-of-control process. Eventually, the use of SD related to product distinguishes between manpower and machinery. When you've pushed the SD to the lowest point, then you've reached the limit of manpower and exposed the shortcomings of the machinery. Understanding SD and its companion NATURAL VARIANCE, enables exact costs to be weighed against material, manpower, and machinery.

Again, SCADA presents the information, and does little to correct the problem other than sounding an alarm. SCADA brings together a "team" effort because it exposes the details of the manufacturing process. In the case of the co-generation example, it is pleasing to note that when the correct information is placed in the hands of the right people, dramatic results can happen.

Areas of Implementation
Multi-Layer Lamination
Pressing multiple circuit layers together with a PREPREG between them results in a successful CURE if there is control of:
- Press Temperature
- Pressure
- Rate of Temperature Rise

Dry-Film Lamination
Lamination of the dry-film to the bare copper board requires control of:
- Pre-heat Temperature
- Roll Pressure
- Roll Temperature
- Conveyor Speed
- Exit Temperatures

Photo or Print Area
The image is transferred to the board with the dry-film on it by means of an exposure sours (i.e. printers or Exposure machines). Control includes:
- Vacuum
- Vacuum Dwell Time
- Light intensity (MILLIWATTS)
- Light Dosing (MILLIJOULES per sq. Cm)
- Room Temperature
- Room Humidity
- Particulate Count

Wet Process
This includes all wet processing performed. The variables include:
- PH
- Oxidation Reduction Potential (ORP)
- Specific Gravity
- Temperature
- Developer
- Etch
- Stripper chemistry pressure
- Conveyor Speed

Distributed Control
Placing a low-cost PLC on the machine provides high-speed control of the process, and input from the production supervisor. Connecting a personal computer to a group of PLC units provides a supervisory control of the machine area. If any element fails (i.e. FORK-LIFT hits the machine) then only that machine stops—the rest of the process continues.

Application Examples
Automotive Electronics
A local manufacturing company made air bag assemblies (clock spring) for General Motors. A series of PLC controllers were connected to a fiber optic LAN system, which fed a SCADA computer. Detailed reports were generated from every step of the operation—temperature, pressure, and dwell time. Failures at any one of twenty stations rejected the product. Several hundred parameters were assigned to each product as it successfully finished the line.

Food Processing Plant
The second largest cannery in the world is located in Northern California. With over 20,000 I/O the plant utilized a number of PLC units to control the process along with a number of man machine interfaces to allow the operator to set conveyor speeds, adjust material routing, and to observe hourly production yields. During the season the plant runs 24/7.

Water Departments
There are over 40 cities in Southern California, each city uses SCADA telemetry to control the flow of water. In recent years all of the Wells (about 50% of Southern California's consumption) draw from the one thousand foot level. When SCADA turns a pump ON a MOTOR feed back signal returns to the SCADA computer. If the pump automatically turns

OFF (current overload) the SCADA system must wait five minutes before turning ON. A brief Start allows the water to drain back down moving the pump in reverse. Turning ON the pump while moving in reverse would "snap" the shaft. In addition, water pressure is critical because most of the underground pipes are old, pressure above 90 PSIG would spring thousands of leaks.

CO-GEN
A 500 MEGA watt power generator was retrofitted to handle special reports for the AQMD. Using an IBM personal computer as a SCADA system connected to the mainframe computer, 7,000 sensor points were monitored and calculated for daily reports. The SCADA computer was placed in a room across from the plant manager's office. The plant manager requested an ANNUNCIATOR page to always be displayed. Here's where the story becomes interesting.

The plant manager considered air to be the most important parameter. Operators wanted a stabilized system; therefore the conflict stability vs. efficiency. The plant manager liked low air because efficiency went up; however, low air created an imbalance and the operators had to struggle to keep the system in balance. Every time the air went up the computer ANNUNCIATOR screen would light up, the plant manager would see it from his office, and the phone would ring in the control room. As advertised in the annual report that year's factory profit per quarter went from $0.4 million to $1.4 million—partly because of air.

The lesson from this example is discovery. The Objective of this SCADA application was data collection—no one ever mentioned air as an important parameter. During the Validation of the Process it because apparent that air was being wasted; thus discovery.

Aerospace
Several large cranes were added to a local aircraft manufacture. Because of the wide span and heavy weights, two cranes on the same structure could collapse the supporting structure and spell calamity. Spread Spectrum serial communication was linked between the PLCs controlling activity between adjacent and remote PLCs. The facility was adjacent to a local airport and was subject to the radio regulations of the FAA. Spread Spectrum was no problem.

Pipeline
Large underground pipelines stretch from the California valleys to the Texas plains thousands of miles to the East. At the break of day, SCADA systems communicate to a number of remote stations and begin collecting the data from the previous day. These reports are "Custodial Transfer" reports that tell the State of California the volume subject to State Sales Tax (a very sensitive issue). Within minutes the reports are sent via Ethernet (inside the company firewall) to the home office in Los Angeles. The reports are highly accurate and based on American Gas Association (AGA) calculations—zero mistakes are permitted.

Building Blocks
- Sensor
- PLC, Programmable Logic Controller
- SST, Spread Spectrum Technology
- Computer
- Software

Sensor
Temperature, pressure, counter, humidity, and energy all impact the process. First, the sensor needs to send a signal to a PLC. Temperature sensors start with 35 mV, pressure sensors start with 0-30 mV, counters are 24 VDC, humidity at 15 mV, and energy (current transducer on power) at 20 VAC. Digital (ON/OFF) sensors are 24 VDC, or 120 VAC. The sensor is a TRANSDUCER ($25), and needs a TRANSMITTER ($200) of either 0-10 VDC analog for short distances (less than 10 ft.); or 4-20 mA DC for long distances (up to 1,000 ft) in order to finish the job. The sensor must be mounted close enough to the process to measure it, and far enough away to not damage the product.

Programmable Logic Controller (PLC)
PLC is a general purpose computer designed to replace Relays. Their costs range from $5,000 to $100 (with RS-232C Ports) each depending on options. A PLC is a nice building block because it can be removed and used again in another application. The PLC uses Ladder Logic Software to design the circuits. Ladder Logic programmers are everywhere, and it is a good idea to either train your staff or hire a part-time programmer. Ladder Logic training is offered by every PLC manufacturer and most distributors. Analog 4-20 mA) inputs use more memory than digital (ON/OFF); and cost ten times more than digital. Something to remember at design time.

Spread Spectrum (SST)
The computer's RS-232C port plugs into one SST unit, and the PLC plugs into the other SST unit. The PLC and computer can be up to 1,000 ft away. Because SST frequencies hover around 950 MHZ, line-of-site is an issue. Low frequency radio signals can bounce off of hubcaps, but high frequency signals need a line-of-site. SST units can be moved, changed, and replaced with few wires to pull (Port to SST).

Computer
Lots of memory, and a moderate amount of disk space are good to have. Serial and ETHERNET Ports are a must. But the key element is software.

Software
Microsoft's Visual Basic (VB) screens are easy to build, communication is simple, and the Active X quickly links the program to data files: Access Database, Excel Spreadsheets, and Word Documents. Proof of Concept using small applications are well suited for VB. Compiler cost is $500. WONDERWARE, INTELLUTION, and a number of good packages are available.

Why Build a SCADA System?
SCADA systems solve problems. You should consider SCADA if you have one of the following issues:

- Product Scrap
- Quality issues
- Multi-Layer Lamination issues
- Dry-film Lamination issues
- Print Area issues
- Wet Process issues
- Customer complaint issues
- Profit margin issues

How to Build a SCADA System?
Building Blocks. Start by outsourcing the first unit. Then bring the project in-house. Sensors are the key to success. Begin with the Sensors and a simple display. Sensors can be connected by 4-20 mA wire or by serial communication (RS-232C). Then use a PLC unit to read the data.

When Should you Install SCADA?
When management understands the importance of SCADA. Until then watch your competition and see how they use it.

Where should you place a SCADA System
SCADA implies an entire system. But you can begin a machine at a time. Build, test, modify, expand, and measure cost versus reward.

- Target the number one PARETO.
- Place sensors on the target machine
- Connect sensors to a PLC then Computer

What Type of SCADA System?
Shop around. There are a number of excellent products, vendors, and people. Select the best.

Future SCADA Developments
Security
Cameras are becoming popular with SCADA. Riding piggyback on the communication lines. Video processing protects people (authorized and unauthorized) from entering dangerous environments. Cameras can be moved and viewed from hundreds of miles away. As more money is moved from company treasuries into security, SCADA becomes the logical solution.

Wireless
The largest cost in SCADA is the wiring. The popularity of Spread Spectrum technology is driving down the price of units; and at the same time increasing the performance. Spread Spectrum now employs Ethernet. Microsoft's Windows 98, 2000, Me, and XP have automatic connection software built-in—how easy can it be?

Personal Daily Assistants (PDA)
PDA have not yet arrived, but are quickly moving towards SCADA. The PDA is already used as a programming device for adjusting timers and Counters in programmable logic controllers. In the not-too-distant future, PCMCIA plug-in modules could cost less than $100 and enable production supervisors, managers, and engineers the ability to plug into an Ethernet hub and extract natural variance statistics from the SCADA system. Touch screen technology and PDA graphics have brought PDA technology to a new level. Marketing has moved PDA in another direction; however, customers are about to move the PDA in to the center SCADA. The United States military has recently requested over a million units to handle sensor and data technology. If that rumor ever turns into reality, the entire PDA market would change over night. The technology is already available, but the product offering is limited.

Client/Server
The notion of a big server, and small client has not gone away. SCADA opens the way for connecting the central office computer to the remote factory equipment. As sensors bridge the gap between transducer (sensor) and transmitter (amplifier) the more attractive SCADA becomes at collecting data. Ethernet within SCADA is a simple connection (10 minutes) to Ethernet within the company. SCADA also works both ways—report and control. Placing RECIPES on the server makes the work order more efficient. Although the technology has arrived, the residual company politics remain (i.e. Engineers and IT do not always see eye-to-eye).

Ethernet
The success of Ethernet is the first step in paving the way to SCADA systems. I/O blocks are now available for direct Ethernet connection. PLC

modules are now Ethernet ready with built-in software. The Ethernet can either be hard-wired or connected via wireless Spread Spectrum technology.

Internet
This holds the greatest promise. As FIREWALLS improve, and customer confidence is increased, then SCADA over the Internet becomes a reality. How does it work? Once the SCADA computer is on-line, that same computer can be connected to a web site via the local Internet Service Provider (ISP), using File Transfer Protocol (FTP). According to the web site files can move into and out of SCADA computer.

Why do it? You certainly don't want to expose private information to unfriendly eyes. But you do want to let your customers know how to reach you, and the strength of your company's resources. The Internet is the future of SCADA. Security not technology is the limiting factor. The success of Ethernet is the first step in paving the way to SCADA systems.

Observation
SCADA is a proven technology. Systems that could loose millions of dollars in damage from a single fatal error are being used every day without incident.

Ethernet and Spread Spectrum Technology (SST) have opened the way for cost-effective SCADA systems.

Discovery is the hidden benefit to SCADA. As engineering, management, manufacturing, and accounting take a closer look at the process they discover new ways to improve the process.

Design Requirements
- Clear Objectives
- Simple Plan
- Foundation
- Building Blocks
- Manufacturing Plan

Configuration
There are a number of excellent configuration programs available to the customer as well as integrators. WONDERWARE, INTELLUTION, NATIONAL INSTRUMENTS, to name a few are valuable tools. Prices start at $1500 and increase in steps of $1500 for drivers, databases, and other tools. WONDERWARE is located in Southern California and has excellent training facilities. All suppliers offer good products, but it pays to shop.

Turn Key
There are other turn key approaches outside the scope of this paper. Contact the panel or search the Internet for a list of SCADA suppliers in your area.

Off-the-Shelf
All of the examples presented in this paper are available from a number of vendors and generally off-the-shelf. PLC manufacturers provide PLC products down to $100 for 8 digital points. Analog units cost $100 per point and start at $500; still a low price.

System Cost
A good rule of thumb is $1,000 a point for the entire system. That rule is based on the following:
- Sensor = $100
- Sensor Controller = $200
- Wiring = $50 (sensor to PLC)
- PLC = $100 (per Input)
- Wireless = $100 (PLC to PC via SST)
- Personal Computer = $100
- Software = $100
- Engineering = $100
- Installation = $150

Return on Investment
A twelve (12) month ROI, can be achieved. The SCADA system quickly identifies manpower vs. machinery. Once discovered then management can adjust the manpower to enjoy savings in:
- Reduced down time
- Reject avoidance
- Re-work avoidance
- Quality improvement
- Product certification
- Scheduling improvements
- Happier Customers

Conclusion
SCADA
Comfortable in the domain of geographically large operations SCADA has changed the way society handles resources. Years ago water companies had reservoirs, but today they have been replaced by the existing underground supply lines. Build-in Ethernet connections have removed the once expensive SCADA command center and placed information throughout key points in a company regardless of geographic location. Sensors and programmable logic controllers have embedded Ethernet hardware to make the job of interconnections much easier.

Spread Spectrum Technology (SST)
SST, has given the Ethernet the ability to reach throughout the plant without the cost of conduit and wiring. In today's factory building a machine means moving a machine. Changes take place on a weekly basis, and moving machinery has become an expensive endeavor. SST minimizes the pain of moving a machine from one end of the building to the other.

Internet

The golden opportunity of factory automation. Low cost PLC units afford easy connection to lamination machinery. Personal computers are now Internet ready, and the Ethernet provides the perfect BACK-DOOR to the factory floor.