The Application of State-of-the-Market CIM to GE's Electrical Distribution and Control Business

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ABSTRACT
With GE's Electrical Distribution & Control Business's (Plainville, CT) drive to win in a slow growth market, it has concentrated on new product introductions and the creation of "Manufacturing Centers of Excellence" for the production of electrical power loadcenters and lighting panelboards. These manufacturing centers are valued in excess of $20MM and apply advanced technologies in manufacturing systems, fabrication and automated assembly.

This paper will review the application of innovative sheetmetal fabrication and automated assembly technologies in GE's ED&C production operations. Specific attention will be focused on the integration of workcell control systems, equipment productivity levels and process quality controls.

INTRODUCTION
The GE Electrical Distribution & Control Business (ED&C) is a business which focuses on supplying the electrical power distribution and controls marketplace with high quality products and superior service. ED&C competes in tough domestic and international markets and has a strategy to not only maintain, but increase, its leading market share. ED&C's approach to meeting competitive challenges and winning increased share is through "Total Automation" - that is a focus on automating all functions of the business for total productivity-not just automating production. One element of the overall strategy is aggressive new product introductions coupled with state-of-the-market Manufacturing Centers of Excellence for low cost production.

"Total Automation" is more than just equipment. It involves the total business spectrum from product definition via CAD/CAM technology to order entry, materials procurement, equipment & process development, quality control, process planning, production, shipment and finally invoicing. It involves the development and integration of multiple computer based systems into a master control network which forms a framework and foundation from which a business launches its cost and product leadership objectives. The result of establishing these integrated systems has permitted improved customer service from the initial proposition phase of an order to short-cycle delivery of product to precise customer specifications via a sophisticated CIM Manufacturing Center.

The GE ED&C Manufacturing Center of Excellence which best reflects the results of our total automation effort is the manufacturing plant in Salisbury, North Carolina, where electrical Lighting Panelboards are produced.

A Lighting Panelboard
A Lighting Panelboard is a device that provides four (4) basic functions to the end user. a) it provides electrical service disconnection b) distributes the energy in a building by breaking the service up into circuits c) provides over current protection and short, circuit protection, and of course, d) provides for the safety of people and property.

It looks very much like the load center in your home that brings in electric power and breaks it up into numerous protected circuits. Lighting panels typically carry more power than your load center, but the function is about the same.

Lighting panels are used in high rise residential applications, or in industrial and commercial environments, and are built for a wide range of applications, some very simple, some very complex. Indoor lighting, outdoor lighting, timing, switching and relaying functions all represent application of lighting panelboards.

SUMMARY
A-Series Lighting Panelboard Project
This aggressive program involved the redesign of an existing lighting panelboard product from a customized (28,000 unique parts) and costly product manufactured at six (6) domestic locations in which each order was requisition engineered with an overall order/build/ship cycle of 3 weeks to a streamlined product (less than 1300 unique parts) which is produced in one (1) location with no requisition engineering
needed and a 2 day order/build/ship cycle time capability.

The Salisbury, North Carolina factory operates with one sixth the number of people required to produce the old style panelboard product and contains the latest state-of-the-art technology for sheetmetal fabrication and automatic assembly. The total investment in this operation exceeds $11.0 million, with an annual benefit in excess of $5.0 million being realized - a 30% cost reduction.

At the core of this automated factory is a unique Flexible Fabrication System (FFS) (Fig. #1) for sheetmetal fabrication. The system contains thirteen (13) machine tools which are linked by a variety of automated material handling units and controlled by a central supervisory computer which directs the processing of over 7,000 tons of raw sheetmetal through four (4) integrated fabrication lines. These fabrication lines incorporate punching, bending, embossing, shearing and forming operations under complete programmable computer control and represents the largest and most complex system of its kind in the world today.
Production orders (Fig. 2) for parts to be produced are communicated nightly to the FFS computer from an automated order entry system located in Plainville, Connecticut, which collects all field panelboard orders from around the country and automatically requisition engineers and verifies them for accuracy. The FFS computer then optimizes the orders to maximize material utilization and minimize processing time for production of lighting panel enclosures.

Additional fabrication and assembly cells are also in place to support the construction of the interiors (busbars, rails, circuit breaker, miscellaneous hardware) of the lighting panels. A Busbar/Z-Rail cell produces parts on a just-in-time basis as demanded by an automated interior assembly cell. The Busbar/Z-Rail cell contains three (3) fabrication lines regulated by GE Series-Six Programmable Controls and linked through a GE Workmaster console. The cell produces the components required by the Interior Assembly cell and maintains a small (Work-In-Process) queue ahead of the cell.

The Branch Interior Assembly Cell then assembles lighting panel interiors via two (2) robotic based workstations linked by an indexing conveyor. The cell assembles a variety of small detail parts and GE plastic components, automatically using four (4) GE A-12 robots regulated by RC 1000 Controls linked to a bank of GE Series-Six programmable control and GE Workmaster workstations. The cell assembles interiors at a rate of 240-260/hour.

**Product Design for CIM**

As was mentioned, the goal of this project was to design and produce a product which has a one (1) to three (3) day customer response cycle. The existing cycle time was two to three weeks, a big challenge.

On day one (1) the order is placed, via an automated requisition engineering system which maintains standardization of design as demanded by our structured product line, and sent via a computer network to Plainville, CT. The IBM System 38 sorts, and prioritizes the orders, define the materials, orders the parts, and determines the configuration of the end product. At the end of the first day the orders are downloaded to the FFS Systems PDP11/44 in Salisbury to prepare for production.

On day two (2) the orders which were downloaded overnight are produced. The system produces in varying lot sizes, with minimum inventory, minimum work force, and minimum cost. The orders are then packed and loaded on a truck.

On day three (3) the order is on its way to the customer.

In order to define what the product had to be we conducted detailed marketing, manufacturing, requisition engineering, and automated proposition system studies. We looked at competing products and manufacturing methods to gain what insight we could and developed strategies for improving product design for manufacturing while further increasing the marketplace features.

Many computerized design tools were applied to optimize the design while minimizing the development costs. One of the key tools used was the GE-CALM CAD/CAM System. CALMA was used for interference detection between mating parts, graphic assembly & test simulation to minimize the number of prototypes, and finite element analysis to evaluate stress and deformation behavior under load. The CALMA System also created numerical control output for machining, and supported the development of fabrication and mold tooling, as well as supported moldflow and thermal stress analysis.

All of these tools shortened the design process provided basis for conducting efficient trade-off analysis and what-ifs to optimize design and provided design capability that would not have been possible using traditional product design methods.
Designing for simplicity, assembly, and automation go hand in hand. What we needed was a single product design that was designed for automated manufacture. We couldn't just automate existing designs, as many companies did so unsuccessfully in the early frenzy of US automation efforts. Parts had to be redesigned so they could be assembled automatically. The overall solution was less expensive, but the part cost and count may have increased. Also, constraints placed on us by UL and the National Electrical code at times caused us to change and even redesign some components.

The end result of this constant struggle was the optimum design for manufacture. A product was designed with standardized parts and improved features that fit the customers needs while minimizing total cost and improving productivity through automated production.

Manufacturing Technology/Processes & CIM

In 1984, at the beginning of this program, many businesses were struggling with how to change their manufacturing plants so as to best apply the latest technological innovations in integrated computer assisted manufacturing while migrating to the just-in-time methods in production. We also struggled with these new technologies in fabrication, assembly equipment and control systems. We took on the challenge of identifying the best methods required--available or not-proven or unproven--and then set out to provision the processes and equipment necessary to achieve our vision of the integrated and automated factory. Our manufacturing and design engineers alike continued to challenge each other in an interactive loop to resolve producibility and automation problems in such a creative manner that it actually lead to several novel solutions and patent awards.

But, what specifically drove us to new manufacturing technology? Certainly, a new streamlined design represented a challenge in that it contained fewer parts, but many new parts where now in GE engineering plastics which was relatively new to us. Could we achieve the tolerances demanded by the design? How would these parts react to handling and automated assembly equipment? These new demands challenged our technical skills and forced us to again be creative and resourceful in seeking clever cost effective solutions.

The product design was only one element of the key drivers which lead to our contemporary factory. No inventory, minimum WIP and lot size of one (1) forced us to totally change how we manufacture and the kind of equipment and methods we adopt. Set against a backdrop of the ever increasing notoriety of JIT -- punctuated by the cry of "Automate, Emigrate or Evaporate" drove us even harder to achieving the maximum productivity possible from our manufacturing technologies. The manufacturing processes that were employed are not new--sheetmetal punching, shearing, bending, embossing, stamping and roll forming are certainly not new.

What is new, is the way we have applied and integrated some of the latest in computerized equipment technology and tooling methods to our product. We set out to find strong capable vendors who were willing to work closely with us as we pushed the state-of-the-art in sheetmetal fabrication and assembly automation technology. In 1984 there were no fully computer controlled and integrated sheetmetal FMS systems to be purchased. It had to be developed and we were going to develop it. We searched especially hard to find a sheetmetal fabrication vendor who was willing to take on the challenge--who had the machine tools and software development resources necessary and who had the know-how to alter our designs where required to achieve a producible product. We found that vendor in Sarago, Italy, and their FFS forms the core of the Salisbury operation.

In assembly, however, we certainly have done a lot to advance the state-of-the-art in design for assembly methods and robotic application. We were very ambitious in what we set out to automate and worked closely with design engineers during the product design phase to guarantee that the top down assembly approach was being maintained.

We did, however, exercise some caution and automated only up to the point of extreme diversity, as is the case in our final assembly area which is manual.

FFS Control System

The FFS Control System architecture is based on a Digital Equipment Company PDP 11/44 supervisory computer which is linked via leased line to a IBM System 38 in Plainville (Fig. #3).
to accept order data automatically on a daily basis. The control system software performs its optimization tasks and produces a two shift schedule for each day shearing material and distributing to the fabrication lines in a balanced and uniform loading sequence. Real time communications are constantly maintained with PDP 11/73 line controllers (Fig. #4) which control all machine and line functions.

Each line controller is a powerful computer resource in itself, and handles all local machine specific tasks as well as peripheral equipment serving the lines. Error diagnostics and other messages are reported to line operators as needed with a constant dialog and part tracking sub-system remaining active at all times. High speed data communications are maintained using standard digital RSX/11M operating features with customized RS232 serial links via HS modems. The system also has the capability to create management reports as requested based on any snap shot in time.

**Plant Operations and Work Force**

The Salisbury, North Carolina plant represents not only the focal point for GE ED&C's application of the latest in CIM technology, it also operates using a novel "self-directed work force concept" that is, a work force organization where the traditional line supervisor and foreman structure is eliminated and ownership for the plant operation, product quality and customer service is distributed to all plant employees. The result is that everyone gets involved in developing, refining and improving both product and process on a continuing basis with a constant focus on process efficiency, product quality and customer service. Not just high tech automation of a product.

**Payoff**

And what were the results of this "Total Automation" effort?

- Lighting panelboard plants reduced from six (6) to one (1).
- Customer delivery cycle reduced from two (2) weeks to three (3) days.
- Total cost reduction of 30%.
- Direct labor reduction of 55%.
- Elimination of requisition engineering.
- Inventory reduced from 45 days to 9 days.

Certainly an outstanding achievement for GE-ED&C—one that has allowed us to fully realize our vision of CIM and the modern factory while keeping our business at the state-of-the-market.

In closing: What is possible with CIM and what is needed to realize it, starts with product design for CIM, not the application of CIM to existing designs. CIM can have impact if you realize the real sequence necessary to achieve it.