Software requirements for high-volume fiber-optic component manufacturing

Integrated process-control system software establishes communication and manages data and information on an automated fiber-optic component assembly line.

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Component manufacturing has come a long way since the early 1990s, when people first started to talk about WDM and other optical-networking concepts in the quest for virtually unlimited bandwidth capacity. As advancements took place in R&D laboratories around the world, device technologies emerged to make the building of the core components of these optical telecommunications networks a reality.

The worldwide demand for these components is an economic force, which catapults new products straight from the laboratory to the manufacturing floor. This phenomenon is affecting the business strategies of startup companies as well as larger established entities.

As these companies are forced to produce more products at lower cost, new challenges factor into the success of their businesses. Component companies today must excel at high-volume manufacturing of products based on new technologies, as well as facing challenges related to material supply-chain management, reduction of production costs, and rapid production-capacity increases, not to mention the hiring and retaining of talented personnel.

The bottom line—running a profitable operation—hasn’t changed. Control over the manufacturing environment and production line is key to achieving profitability in this climate. Henry Ford faced this same challenge almost a century ago in the automotive industry. The semiconductor microelectronics industry went through a similar evolutionary growth phase in the 1970s, as integrated-circuit manufacturing evolved into an attractive business economically.

Today, the fiber-optic optoelectronic components industry is looking for its own Henry Ford. The industry needs a solution to the manufacturing of these new products—economically and in large numbers. Achieving this objective requires a “repeatable” manufacturing process. This type

Figure 1. A conceptual representation of a next-generation fiber-optic component manufacturing factory.
of production leads to higher yields and reduction of manufacturing costs. Automation based on an integrated process-control system is one way to accomplish this goal.

**Why automation?**
In an automated manufacturing environment, dependence on the operator is significantly reduced, leading to higher yields. A significant amount of process and technological know-how is captured and retained in the computers and machinery rather than in the minds and hands of skilled operators. Operators often need years of experience to produce high-quality products. Those same skills can be captured in a properly designed assembly line. It is not necessary to clone the watchmaker by 100-fold to manufacture fine Swiss watches in high volume.

Such an approach greatly reduces production cost. In high-volume manufacturing, a dominant cost issue is the cost of labor. Reducing the number of workers through automation and designing the production line so relatively unskilled, low-cost technicians can maintain and run it, can significantly lower production costs. It also lowers the cost of training the work force.

To a certain extent, when production volumes are not very high, it is possible to use more and more workers to perform the same manual task. As the throughput numbers increase, however, the problems associated with hiring, training, and managing numerous employees, while ensuring that the manufacturing process is “repeatable,” exponentially multiply. Beyond a critical threshold, it is impossible to run an economical manufacturing operation in this way. The fiber-optic manufacturing industry is currently at this crossroads.

**Better approach**
The assembly line in a fiber-optic components factory could consist of islands of automation, each implementing one stage of a complex yet departmentalized process. The parts could be moved from one machine to another in device carriers, also called pallets. These pallets easily dovetail into the docking bays of various machines, which are equipped with the proper toolings and fixtures to accommodate a specific device undergoing a specific process. An integrated process-control system software establishes the proper communication protocol among various machines and manages smooth flow of data and information.

A supervisory station is the link between this assembly line and other assembly lines at other parts of the factory or other manufacturing sites. It also serves as the local node for managing material supply-chain issues such as on-time ordering of parts from vendors or service requests (see Figure 1).

In many factories, the machines are fully automated and the time for part loading and unloading is minimized. Consequently, one operator is able to operate more than one machine, even several machines, resulting in cost savings associated with a smaller work force.

A key building block of an automated assembly line for fiber-optic components is integrated process-control software. The software system controls instrumentation and performs data acquisition. In a small scale, writing a few lines of code using any standard computer programming language can produce the same functions in a limited way. That is typically how system integrators generate computer programs to operate the systems they offer to their customers. This approach works fine in a laboratory environment or a low-volume manufacturing environment, where one system or a handful of separate systems run their own independent procedures and routines. It is not adequate in a high-volume setting, however.

High-volume production requires automation software that serves as a machine controller as well as a process automation tool. Such software platforms are commonly used in more mature industries such as the semiconductor industry and are essentially based on a computer numerical-control concept.

True factory automation software is based on distributed computing. Multiple events happen concurrently, which means that the software parallel processes various activities simultaneously. For example, as a machine is aligning and connecting an optical fiber to a laser diode in the assembly process, the software has to concurrently run the alignment algorithms, perform motion-control tasks, and keep track of safety factors. Various tests and measurements might also need to be performed on the partially completed device to characterize its properties (see Figure 2). These characterization procedures generate lots of data that needs to be recorded and managed. The data has to follow the device from machine to machine as the product moves down the assembly line. Therefore, a high level of connectivity is required across the various machines operating at the different stages of production.

Factory-floor communication proto-
Automation process

The applications-and process-oriented requirements of these software systems presents other challenges. Many of the optoelectronic components in demand are designed around new technology and applications. To be built in the proper way, these devices require the knowledgeable mind and skilled hands of a high-level technician or engineer. This technological know-how and manual dexterity has to be somehow captured, then implemented by an automation platform. The goal is not to entirely remove the human factor from the equation, but rather to eliminate the influence of the human factor on the process to achieve repeatability, a fundamental requirement for obtaining high yields.

To further compound the challenge, there is the issue of device variety. The fiber-optic-components market is advancing so rapidly that devices are constantly changing their forms and shapes in almost a mutational evolutionary fashion. The production lines for building these devices must be highly modular and designed for multitasking. Similarly, the process and manufacturing software should be engineered so that it is highly modular and application-oriented. Software with a library of basic application procedures and subroutines built into it can be expanded by a manufacturer's engineers as the company develops new ways of manufacturing its specific products. A library of algorithms, application-oriented subroutines, and process recipes serves as a toolbox, which contains the building blocks of a complete process sequence for a particular product. As the product evolves or is replaced by newer innovations, manufacturing process engineers can build new process sequences using most of the same fundamental building blocks without needing to write an entirely new code from scratch. This approach gives the software the level of modularity required in the fiber-optic component production lines.

Once the manufacturing process engineer creates and finalizes a new process sequence for the manufacturing of a product, the new process must be implemented on the production line. On the manufacturing floor of a high-volume production factory, numerous technicians may work on different stages of the assembly line. Their skill levels and control privileges, as well as security clearances, cover a wide spectrum. The process-control software needs to address this issue with a scheme of privilege settings. An automation software platform may offer multiple levels of privileges to cover the work requirements of the unskilled technician all the way to the chief engineer.

In today's global economy many manufacturers of fiber-optic components have factories and production lines set up in different locations around the world. The same manufacturer might be using a process-control system in both its factories in North America as well as in a factory in Europe or China, all of which brings up a communications issue. The operators in each of these countries speak different languages, yet the same software is used by all of them. Therefore, process-control software should incorporate graphical user interfaces where possible and support multiple languages.

Automating change

As the telecommunications needs and requirements of the world evolve, the optical telecommunication devices that constitute the building blocks of these new optical networks need to change, too. The high demand for the technology that makes the realization of these devices possible calls for automated photonic components factories. This high-volume manufacturing requires new automation software platforms and integrated process-control system software to make these facilities operate in an economical and profitable fashion.

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