A Detroit-based automaker needed a turnkey modular manufacturing system capable of producing two types of front-wheel drive transaxles. One transaxle type is a traditional clutch/planetary front-wheel drive unit; the other is a transaxle for hybrid vehicles. The manufacturing system had to be capable of producing a batch size of one with any product mix, and it needed flexibility to meet future manufacturing requirements.

Our company, Kuka Assembly and Test, designed the solution. We're an OEM and integration company providing manufacturing solutions to automotive manufacturers worldwide. These solutions include assembly and test systems for engines, transmissions, axles, suspension systems, steering systems and many other automotive components.

For this project, we employed automation and power distribution components from Siemens Industry (www.usa.siemens.com/automation). Siemens components and their Totally Integrated Automation architecture in particular are our standard and preferred automation solutions because of their innovative technology, worldwide acceptance, long-term reliability and comprehensive global support.

Modular manufacturing brings benefits
The manufacturing system is divided into two major areas: the dry line and the wet line. The dry line is also referred to as the main line. The transaxles are assembled on the dry line. On the wet line, they're filled with the appropriate fluids and tested.

The heart of the main line is a unique vertical conveyor system that uses a special carrier/platform design. This carrier/platform is also referred to as a pallet, constructed specifically for this project and designed to accommodate each transaxle. The pallets mechanically latch into the vertical conveyor guide. Rollers built into the vertical conveyor move the pallets. The wet line is a traditional horizontal conveyor with pallets designed to accommodate each type of transaxle.

The conveyor was designed and built into 10-foot sections to standardize our modular design, and to facilitate disassembly and reassembly at the customer’s site. The entire line was constructed and tested in our shop prior to shipment to the customer.

Because the conveyor for this modular manufacturing system was so large, there were several segments assigned to it according to various types of manufacturing tasks. A segment is a self-contained portion...
of the physical conveyor system and can include several sections depending on the tasks and functions performed within the segment. Basically, a segment includes everything necessary to operate the conveyor transport system including pallets, rollers, the drive assembly, and the components and circuits required to keep the pallets moving on the conveyor. The actual tasks associated with assembling the transaxles occur at stations, which can be either manual or automatic. The dry line has 35 manual stations and five automatic stations to meet the customer’s production rate of 900,000 transaxle units per year.

A manual station is where the operator performs assembly tasks, which involves placing parts into the transaxle as well as the fasteners that secure them (Figure 1).

Automatic stations don’t require operators. At automatic stations, the fasteners are tightened to their appropriate torques. Also, automatic stations are equipped with devices that take tolerance measurements automatically and provide the data to the quality system computer.

The process of assembling the transaxles starts at the load station, which is a type of manual station. At the load station, the transaxle halves are placed on their specific pallets. Once placed, the transaxle stays with the same pallet throughout the assembly process.

If the customer ever needs more capacity, stations can be easily added. Also, if workflow needs to be adjusted, the manual stations can be easily moved to a different spot along the dry line conveyor.

**Distributed automation architecture enables modular manufacturing**

Every line segment and every station—whether manual or automatic—have these criteria in common (Figure 2):

- They each have their own automation
- They all integrate real-time control, safety and communication
- They all communicate via Profinet protocol on an Ethernet network
- They are all part of a distributed architecture.

The radio-frequency identification (RFID) system is a key component because of the autonomous yet interdependent nature of each station on the line. On most of the stations, we used a typical RFID read/write module for basic pallet/product location and station instructions. However, we used high-speed RFID communication modules for line segments where large amounts of data needed to be moved on or off the RFID tags.

The controls for a typical manual station include a PLC, an HMI, a managed Ethernet switch and a RFID read/write station. Manual stations also include ergonomically-designed lifting devices to help the operators position the drive halves, if necessary.

The controls for a typical automatic station include a PLC, an HMI, a managed Ethernet switch, a RFID read/write station, automatic assembly tools and an assortment of automatic gauges and/or other measurement devices. Automatic stations also have servo drives and motors that operate the automatically-positioned measurement devices.
The modular manufacturing system uses segment controllers to oversee and control the transport system, which moves the pallets along the conveyor. The segment controllers control pallet motion, keep track of pallet location, and communicate with adjacent segments.

Segment controllers have the same basic control components included in manual stations. In addition, they have components that control the conveyor transport system elements. These added elements include disconnect switches, motor starters and VFDs which operate the turntables that flip the pallets when necessary (Figure 3).

We leveraged the power of Profinet to communicate information from scheduler software running on a PC to the PLCs, and from the PLCs to the RFID tags on the individual pallets. The scheduler PC downloads recipes and quantities to the PLCs—so every PLC on the line then knows what transaxles to build, how many to build, and how to build them.

Each pallet has an RFID tag. While at the load station, a camera reads the 2D-code serial number from the transaxle. It sends that information to the load station PLC, which sends it to the pallet’s RFID tag.

From the load station, each pallet travels from station to station on the dry line. As the transport system presents the pallet at each station, the system reads the RFID tag, which contains the status for that transaxle.

At a manual station, operators place parts in the transaxle halves and verify they’re in the proper locations. The system writes the appropriate information to the RFID tag, and the transport system moves the pallet to the next station.

When a pallet arrives at an automatic station, the RFID tag is read, which initiates the appropriate task sequences for that station. For example, nutrunners tighten the fasteners placed by the operators.

Nutrunners are servo-driven assembly tools with torque measurement capabilities. This type of tool enables automakers to manufacture critical assemblies with precision and repeatability. It also facilitates an electronic audit trail for every serialized assembly that the automaker manufactures.

Other tasks performed at automatic stations include quality checks. Automatic gauging performs checks and sends measurement data to the quality system.

At one of the line’s most complex automatic stations, robots put the transaxle halves together (Figure 4). One robot dispenses an RTV-type sealing material onto the flange of the appropriate transaxle half. Another robot then assembles the transaxle halves. The assembled transaxle, along with its pallet, is transferred by overhead gantry to the wet line where it’s filled with fluids and tested.

**Tight automation integration facilitates information exchange**

The modular manufacturing system required a distributed control architecture. The system also needed fail-safe CPUs and RFID read/write capabilities. The I/O components required ingress protection meeting IP65, sometimes greater. To meet these requirements, we turned to Siemens and their local distributor Electro-Matic (www.electro-matic.com).

Siemens provided an efficient distributed architecture configured to communicate via the Profinet and Profisafe industrial networks. These systems included Simatic S7-317F fail-safe programmable controllers, ET 200pro distributed I/O, MP 377 Multi Panel HMIs, RFID read/write systems, RF170C RFID for automatic and manual stations, RF180C RFID high-speed communication modules for Profinet, and Scalance X208 managed Ethernet switches. Siemens also provided disconnect switches, motor starters, Sinamics servo drives, and VFDs. Many of these components have an IP65 rating, and some are rated IP67.

The automation and control components we used for this project, based on Siemens Totally Integrated Automation, are specifically designed to work together within a distributed architecture. Although the architecture supports physically distributing components where they’re needed, it also allows multiple control functions to be integrated within the same system.

Just a few years ago, different devices required different protocols to communicate with their hosts. Now, with Profinet, we can design systems using one network from the top to the bottom—down to the device level, such as the RFID tag.

In this system, safety is integrated as well as distributed. Older technology necessitated hardwiring safety I/O back to a separate control system. Now, safety components such as switches, machine guards and light curtains can be integrated into the main controller, and safety I/O can communicate to the controller via the same Profinet cable used by standard I/O. Also, both safety and standard I/O don’t have to be confined to a cabinet, as most of these components can be machine-mounted.

If the customer needs to make changes to accommodate workflow or increase capacity—automation components can be easily moved or added as everything easily disconnects, moves and reconnects including power, controls, communication and safety components. Because of the manufacturing system’s modularity and the control system’s distributed architecture, installation at the customer’s site was greatly simplified. Once the conveyor was
reassembled, the distributed controls and power connectors could be reconnected by just plugging them in.

By using this modular design approach, we saved a significant amount of installation time. With older automation technology, manufacturing systems were assembled and tested in the shop. The systems were then taken apart in to sections for shipping, and then reassembled on site. All sections had to be re-wired on site and every I/O point had to be verified, a procedure that could take three or four months.

With the new automation system, we didn’t have to pull wires and we didn’t have to re-terminate when we reassembled at the site. This modular system design with its distributed control plug-and-play architecture saved about 60% of the installation time, a significant benefit for any OEM company.

Additional time savings were realized during commissioning. When the system sections were put back together at the customer’s site, the automation components communicated instantly via Profinet. Virtually everything worked right away, and if we had a node that didn’t respond correctly, the Profinet network told us exactly where it was and what was wrong.

**Integrated benefits, distributed value**

Siemens and Electro-Matic helped us meet our goals for this project, as we were able to provide integrated control using a distributed architecture over a common Ethernet network. Using Profinet protocol instead of having to use two or three different networks, enabled us to deliver a distributed system with integrated safety.

The automation system diagnostics and messages are easily understood by a factory floor worker, so maintenance techs can diagnose the system without needing to plug in a laptop. The techs are able to successfully maintain the controls and the network by viewing the HMI screens, by monitoring the fault lights on the controllers and managed switches.

Using Siemens Totally Integrated Automation control architecture was very attractive from a cost perspective as well as saving the company approximately 15% on the project in terms of the automation hardware.

Although the individual cost of distributed architecture components with IP65 and IP67 ratings cost more than their cabinet-bound counterparts, the total assembly and installation costs were much lower. Fewer cabinets were needed, and those that were necessary were much smaller. There was also less wiring, lower labor costs, and shortened testing time.

This particular system was the third in a series of transmission manufacturing systems. As a result of this project, the modular manufacturing system’s planned annual production volume increased by a factor of 3.5. Plant personnel were able to come up to speed quickly on the new automation system, and diagnostics and maintenance have been greatly simplified.

**About the authors**

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