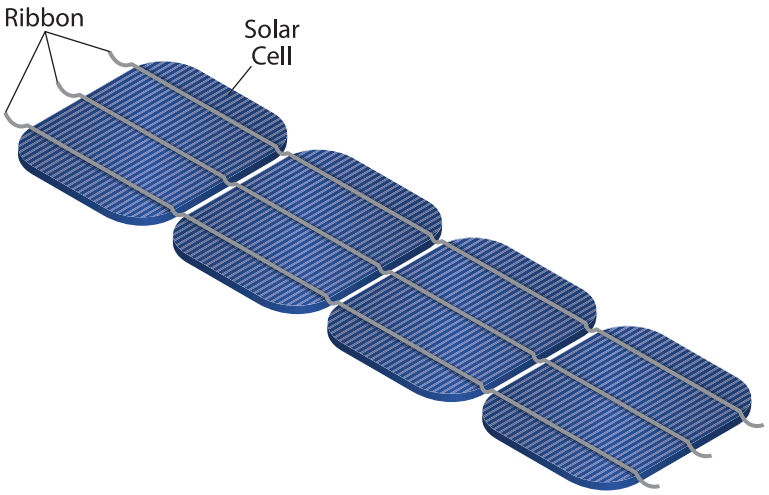
Automation Control for Photovoltaic Stringer Equipment

Advantages

- **Process Optimization** - Closed loop temperature control of the soldering process helps reduce thermal stress and helps prevent cracking or warping
- **Advanced Process Control** – Tighter control and reduction in raw material usage helps reduce panel manufacturing and equipment operation costs
- **Greater Flexibility** – Faster equipment changeovers to handle two or three bus bars and various cell sizes
- **Faster Development/Troubleshooting** - Pre-built and tested Add-On-Instructions (AOIs) with Human Machine Interface (HMI) faceplates provide detailed diagnostics for I/O, Ethernet switches and motion control
- **Modular Code** – Equipment Modules, Control Modules and State Machine structure offers code reuse and helps simplify customization of states to meet SEMI standards
- **Data Access** - Pre-built information enabled code structures for quicker implementation of data collection needs for genealogy, Overall Equipment Effectiveness (OEE), production scheduling and historical process data
- **Integrated Motion** - One development software platform for motion and control; smooth, precise motion helps eliminate jerk that could lead to substrate breakage or material defects; vision assisted robotic motion
- **Robot Integration** – Flexible options for integrating third-party robots; Kinematics option for integrating SCARA and Delta robots directly
- **Common Network** – Control components including HMI controllers and I/O can be connected via the EtherNet/IP™ network with no additional software required for configuration
- **Component Portfolio** – Broad portfolio of safety components to help reduce risk of damage to equipment or injuries to personnel



Solar cells are connected together to form a string. Multiple strings are combined to form a photovoltaic panel.

Overview

Electrical interconnection of solar cells is a critical step in manufacturing silicon based photovoltaic solar panels as it impacts yield, throughput and final module efficiency. Stringing cells together allow the cells to form a larger power generation system. Strings of cells are laid side by side and connected together to make a photovoltaic solar panel.

Stringer equipment is used to connect the solar cells. A stringer solders inter-connecters (ribbons) to a number of photovoltaic cells to make photovoltaic cell strings in series.

The primary sections of stringer equipment include cell loading and alignment, ribbon feeding, soldering, inspection and string unloading.

Cell Loading & Alignment

Solar cells are generally unloaded from trays or pallets using a pick-and-place style robot. The cells are then aligned on a conveyor in preparation for transfer to the soldering station. A vision system is typically used for cell alignment, although some stringers may be equipped with mechanical alignment features instead. Cell edge, bus bar position or both may be used for cell alignment.

During the loading process, a vision system may be used for inspection of the cell for cracks or breakage. Any damaged cells are discarded prior to the soldering process.

Ribbon Feeding

Most stringer equipment is offered with the option for stringing 2 or 3 bus bar cell types. Up to 3 ribbons are uncoiled from spools and fed to a fluxing station. The ribbon and cell meet at the soldering station where the ribbon is stretched, clamped and cut to length.

Flux Application

Flux is applied prior to soldering the ribbon to the cell. The flux may be rolled or sprayed on the ribbon or directly on the cell's bus bars.

Soldering

The soldering step is the most important processing step for producing a high quality, visually appealing solar panel that is also electrically sound. Solar cell breakage can occur during the solder process due to thermal stress. Cell thermal stress is minimized by carefully preheating the cells before the soldering process followed by a controlled cooling phase afterwards.

The technology used for the soldering process is often one of the main differentiators between stringer equipment manufacturers. Various soldering technologies are used including infrared lamp, induction heating, laser and hot air.

Inspection

After soldering, the strings may run through a second vision system to inspect the alignment of the cells and ribbon and to look for cracks and other defects.

String Unload

Completed strings are rotated and then transferred into stationary trays or laid up directly onto glass.

The stringer operation is typically controlled by a Programmable Automation Controller/Programable Logic Controller (PAC/PLC) and HMI operator interface. The graphical operator interface provides interactive displays that are used to easily setup and operate the equipment. Connection to a production line HMI and plant-wide information systems are also offered as part of the equipment or optional add-ons. Production data, historical data logging and OEE can be stored and calculated to optimize equipment operation.

The most complex area of the stringer equipment is the soldering process. As the wafers are cut thinner to reduce raw material cost, thermal stresses that occur during the soldering process can lead to cell breakage. To reduce the possibility of cell damage, the cell temperature and solder process cycle need to be tightly controlled.

The solder cycle starts with heating the cell as it moves along through a number of temperature zones toward the soldering head. Once the cell reaches the soldering head, the head is lowered into position just above the cell. To keep the ribbon taut and in the proper position, the ribbon is held down with pins as the soldering process occurs. When the solder process is complete, the soldering head is withdrawn and the pins are released. The cell then moves through a number of cooling zones. The temperature profile with a quick heating ramp, a soak period and a cooling ramp helps reduce the cell thermal stress before, during and after the soldering process.

Servo motion control is used extensively within the stringer equipment. Pick-and-place robots or Selective Compliant Assembly Robot Arm (SCARA) robots are often used for loading the cells. Linear or rotary axes are used in various capacities. Examples include transferring the cells from zone to zone, raising and lowering the soldering head, flipping the completed strings, and ribbon handling. Motion commands must be smooth and precise to prevent cell or string damage during cell or string transfers.

Bernoulli grippers are widely used for handling the cells and to gently pick up completed strings with minimal force. The airflow over the surface of the cells generates a lift. As cells and strings are moved, no jarring or shaking can occur, otherwise the Bernoulli grippers could lose suction and drop the cells. Precise stops are also important to prevent the cells from bumping into other objects.

A safety system using machine guarding helps protect operators from injury. Robots, motion movements and high temperatures are examples of machine hazards that need to be mitigated. Safety components including safe-off options, safety relays and door switches are often deployed to help prevent damage to equipment or injuries to personnel.

Rockwell Automation and its partners offer modular options to help monitor and control key areas of the stringer equipment. Central to the solution is the Rockwell Automation Integrated Architecture™ which brings together a powerful multi-disciplined control engine, seamless networking, a scalable visualization platform and the information technologies needed to help you lower your Total Cost to Design, Develop and Deliver℠ a machine.

Unlike conventional control architectures, the Integrated Architecture provides fully integrated, scalable solutions using a single control platform and a single development environment. This helps machine builders shorten design cycles and increase their focus on innovations that lead to a competitive advantage.

Process capabilities inherent in the Logix control engine can be used to control the temperature zones before and after the soldering step. The soldering step can utilize advanced process control (APC) features like fuzzy logic to optimize the closed loop temperature control.

Kinetix® integrated motion with Kinematics helps to simplify robot control. Using the Allen-Bradley® ControlLogix® family of PACs and the Rockwell Software® RSLogix™ 5000 programming software, OEMs can integrate simple, multi-axes robot control into the main Logix control platform. OEMs can program articulated independent/dependent, SCARA, and Delta robots natively within the ControlLogix controller using built-in motion instructions. Motion is programmed using Cartesian coordinates and the controller handles the Kinematics transformations. This helps reduce both design and programming time and cost.

In addition to helping to provide the most advanced integrated robotic control solutions, Rockwell Automation also aligns with leading robot and machine vision suppliers through the Rockwell Automation Encompass™ partner program. Vision systems can be implemented with cameras that are integrated with the ControlLogix PAC over EtherNet/IP™. For applications that still require a separate third-party robot controller, EtherNet/IP can also be used to coordinate the robot with the rest of the stringer control.

The Kinetix servo motion control solution can be used for feeding the ribbon to the proper length, moving the cell from station to station, and raising and lowering the solder head to the precise position above the cell. Once the strings have been formed, the motion controller can smoothly take the completed strings and load them in trays or place them directly on the glass in the lay-up station.

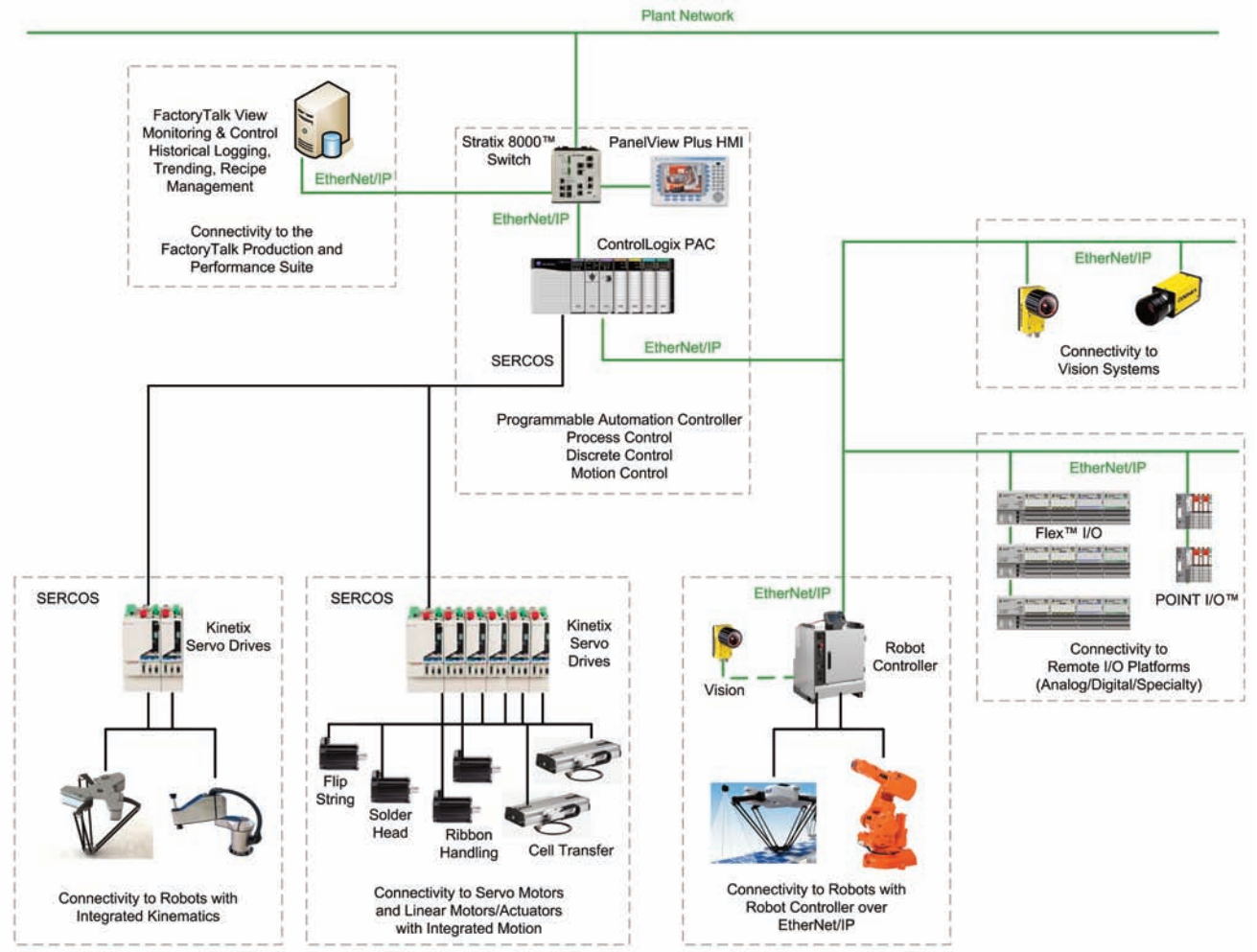
A variety of Allen-Bradley industrial and safety components can also be used on stringer equipment. Power components, such as circuit breakers and contactors, help monitor motor performance. Tower lights, push buttons, and signal devices help improve operator productivity. Safety components including safety relays, safety contactors, safety mats and emergency stop devices help maximize machine uptime while helping to protect operator personnel.

The scalable FactoryTalk® View software can be deployed on a PanelView™ Plus terminal running FactoryTalk View ME for local operator control or integrated into a complete line environment using a Rockwell Automation industrial computer running FactoryTalk View SE. This allows OEMs to offer visualization options for both stand-alone machines and integrated production line machines.

Additional production disciplines contained within the FactoryTalk Integrated Production and Performance Suite can be used for the critical data necessary to help monitor and control the stringer equipment. Data collection, historical logging of process parameters, real-time trending and enhanced diagnostics are capabilities that can be deployed to improve equipment operation.

Typical Architecture

Stringer Equipment with Vision and Robotics



Rockwell Automation solutions deliver improved production capabilities and help reduce total cost of ownership by providing unparalleled functionality, flexibility and scalability. Machine builders can respond more quickly to customer or market demands, reduce maintenance costs and downtime and easily gain access to actionable plant and production information for improved management and decision-making.

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Publication OEM-AP059A-EN-P –August 2009