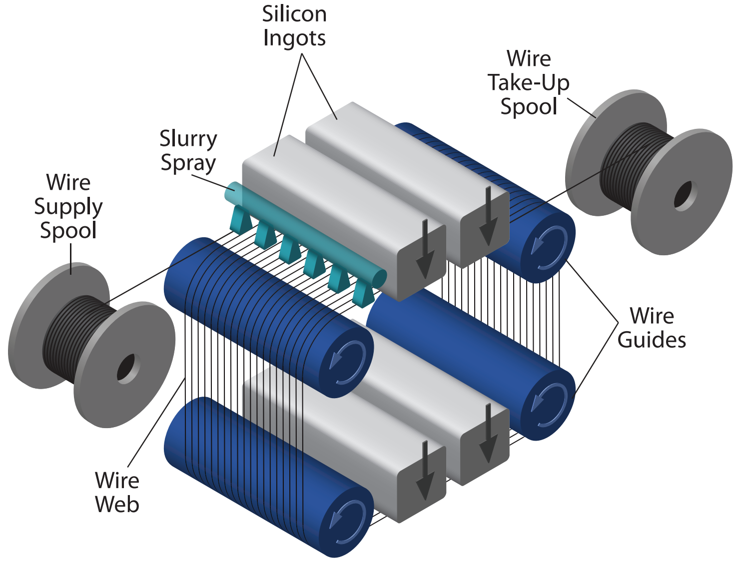
Automation Control for Wafer Slicing Equipment

Advantages

- **Integrated Motion** — One development environment for motion and control; Smooth and steady motion to prevent wire breakage
- **Kinetix® Motion** - Position to tension mode on the fly; Servo torque limits (set or limited by position)
- **Integrated Drive Control** — Pre-built and tested Add-on-Instructions (AOIs) and Human Machine Interface (HMI) faceplates speed deployment of networked drives
- **GuardMotion™ Safe-off Function** – Servo drive remains powered during maintenance tasks allowing faster machine restarts and enhanced system availability
- **RSLogix 5000 IEC 61131 Programming Languages –** Structured Text allows real-time implementation and execution of complex algorithms for the wire velocity profile
- **Faster Development/Troubleshooting** — Pre-built and tested AOIs with HMI faceplates provide detailed diagnostics
- **Modular Code** – Equipment Modules, Control Modules, and State Machine structure offers code reuse and easy troubleshooting
- **Data Access** — Information enabled code structures pre-built for quicker implementation of data collection needs such as Overall Equipment Effectiveness (OEE) and historical process data
- **Process Optimization** — Advanced Process Control (APC) and closed loop process control improves process consistency; Allows flexibility to use thinner wire to slice thinner wafers without compromising throughput
- **Broad Safety Portfolio** – Sensors to detect wire breakage and door interlocks to help deter entry during the slicing process



Overview

Silicon wafers are used as the substrate material in the manufacture of solar photovoltaic (PV) cells. The wafers are sliced from silicon ingots (blocks) using wire saws in a process known as wafering. Since the silicon substrate is one of the most expensive materials used in the manufacturing process, reducing manufacturing costs and waste is critical to lowering the overall cost of solar power generation.

Wire saw technology is an integral element in reducing the cost per watt and allowing PV to reach grid parity. Advances in wire saw technology to cut thinner wafers have reduced the amount of silicon material required to produce electricity.

Silicon PV wafer thickness has decreased over the years from over 300µm to less than 200µm. This trend is expected to continue with the possibility of wafers approaching a thickness of 100µm. By reducing the wafer thickness, more units can be produced out of a given volume of raw material and silicon consumption can be reduced considerably.

The three main advantages of wire saw technology are high throughput, small kerf loss (amount of material lost from the cutting process) and a high quality finished surface.

In most wire saws, a single wire (diameter in the 100 - 180µm range) is fed from a supply spool (several hundreds of km long) through a tensioning system onto wire guide rolls. These rolls are grooved at a constant pitch and the wire is fed around the rolls several times to form a web of adjacent parallel wires. The grooves that guide the wire must be accurate, and the rolls themselves must be stable against thermal changes in the machine to avoid warping the silicon block during slicing.

The wire tensioning system should tension the wire uniformly at a constant load and the control loop needs to be fast enough to compensate for occurring fluctuations on the supply spool of the wire. Motors rotate the wire guides which move the entire wire web at a speed (5-20 m/s range) that can be adjusted during the cutting process. A collection spool on the output side of the machine receives the used wire.

Two types of wire can be used in the wire saw – stainless steel or diamond wire. Stainless steel wires are designed to be used with an abrasive slurry (usually a mix of silicon carbide and glycol or oil) and diamond wires are used with water. The abrasive slurry on the stainless steel wire or the diamond particles affixed directly on the diamond wire form the cutting media to cut through the silicon blocks.

Nozzles continuously spray the moving wires with either a silicon carbide slurry (stainless steel wire) or water (diamond wire). As the silicon blocks are pushed into the wire web, the slurry-clad wire cuts the ingot into thousands of wafers with a thickness determined by the pitched grooves of the wire guide rolls. The table feed will feed the silicon block precisely into the wire web to prevent misaligned cuts.

Slurry viscosity affects the efficiency and cutting time. As the water content increases, the slurry flows at higher rates and can shorten cutting times. However, if the slurry viscosity is not viscous enough, there will be an insufficient amount of abrasive being used and the cutting time will begin to increase.

The effect of wire speed differs between stainless steel and diamond wire usage. As the speed of a stainless steel wire blade increases, the cutting time decreases. However, as the speed of a diamond wire blade increases, the amount of abrasive particles being removed from the wire increases - ultimately leaving the wire bare and free of any abrasive to do the cutting.

It is important to control the critical parameters that often interact with one another. The wire saw must precisely balance and control wire speed and tension, table speed, slurry viscosity and temperature, and abrasive characteristics to achieve consistent wafer thickness and shorten cutting time without wire breakage.

Thinner wires, higher cutting speed and load all impact the cutting wire and the risk of a wire break. Since all silicon blocks are sliced simultaneously, if a wire breaks, all blocks must be discarded resulting in lost productivity. Wire tension needs to be monitored very closely to help reduce lost time/production and also help eliminate a safety hazard. Load cells are typically used to monitor wire tension. If the load cell feedback drops to zero, it is an indication that a wire break has occurred and several feet of extremely sharp wire is whipping around at very high speeds.

As wafer thickness decreases, the sawing process can experience additional challenges. Micro-cracks and bowing can occur if the process is not tightly controlled. Wire speed and tension, cutting fluid viscosity and temperature, and table speed are all important factors that must be carefully controlled. Manufacturers have to balance these factors to maximize productivity.

Ultimately, wafer quality is the most important factor for crystalline silicon PV cell manufacturers. Wafers must be free of surface damage like saw marks and micro-cracks and have minimum thickness variation and warp.

Solution

Rockwell Automation offers solutions to help monitor and control the wire saws used to slice the silicon ingots into wafers. Central to the solution for wafer slicing equipment is the Rockwell Automation Integrated Architecture™. Integrated Architecture 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. It allows machine builders to build standardized code with improved access to production and diagnostic information. This helps machine builders shorten design cycles and increase their focus on innovations that lead to a competitive advantage.

The Allen-Bradley CompactLogix™ Programmable Automation Controller (PAC) or ControlLogix® PAC can help control the wire saw by taking advantage of the powerful process control capabilities inherent in the Logix engine. Kinetix integrated motion control capabilities and the premier integration of networked drives can also be used.

The wafer slicing machine is equipped with a number of sensors for the optimization and control of the sawing process. Some machines are equipped with simple pushbuttons and pilot lights for the operators to utilize while others use a PanelView Plus™ local operator interface terminal. The PanelView Plus HMI can display a broader range of information regarding the machine state, diagnostic messages and troubleshooting guidance. From a maintenance screen, machine parameters like table feed rate, slurry flow rate, slurry temperature, wire speed and tension can be programmed.

Servo motors are used to control the table position and feed rate of the silicon blocks as they enter the wire web. Servo motors are also used to unwind and wind the cutting wire and maintain tension on the wire used during the cutting process.

Encoders are used for position feedback and tachometers are used for monitoring the speed of the cutting wire as it is fed through the wire guides. The wire guides are usually driven by dedicated motors and the bearing temperature is monitored continuously. The wire is routed through various pulleys and tensioning arms which help keep the wire tension and movement smooth and steady reducing the risk of wire breakage.

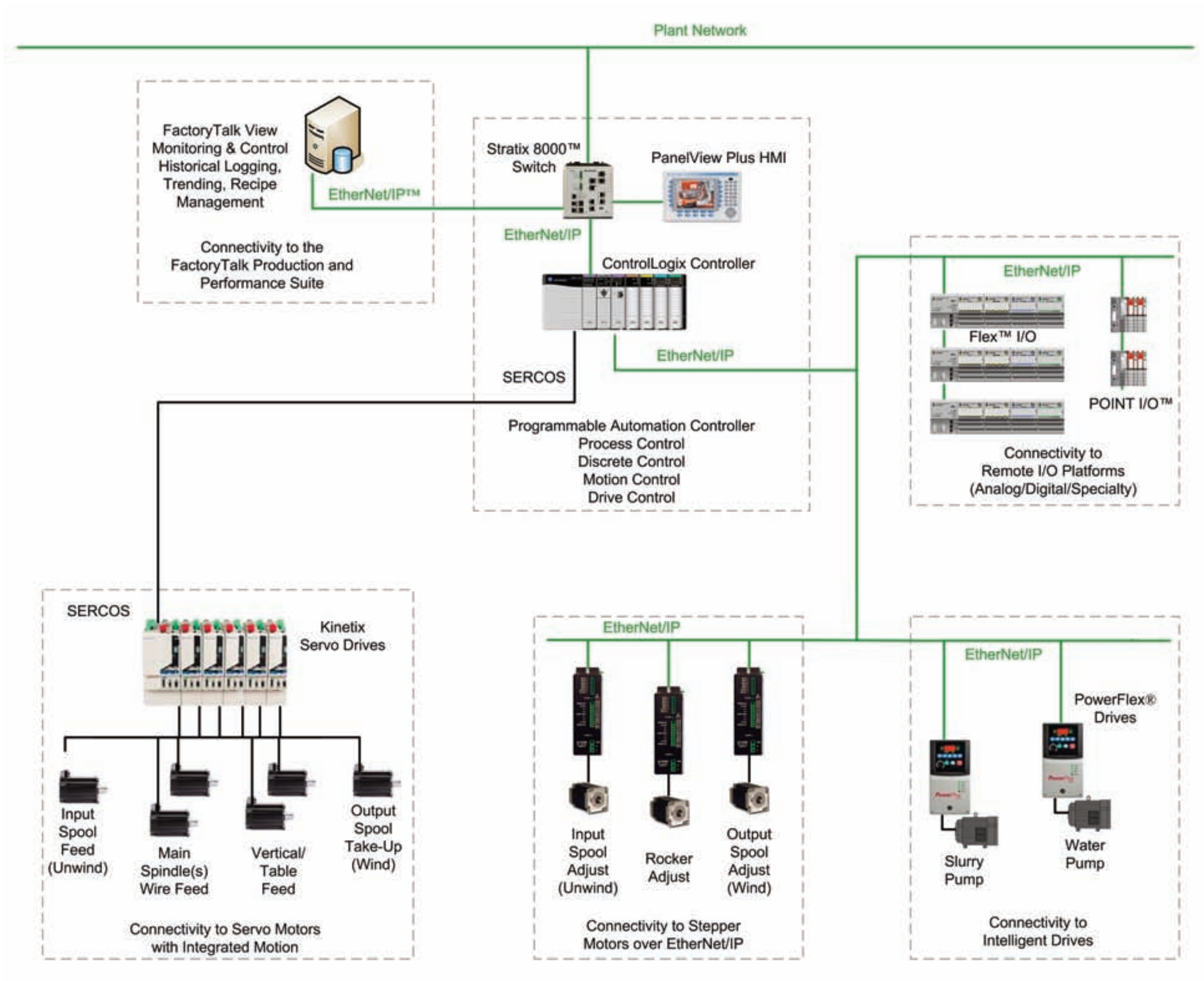
A local slurry station or connection to a centralized slurry delivery system is usually offered as an option. Slurry and mixing pumps are controlled with variable speed drives to adjust the flow rate of various additives such as slurry, water, glycol or oil. The slurry also acts as a cooling agent as the silicon block is sawn. The flow and temperature of the slurry is monitored carefully via sensors at multiple locations. Air which is also used for cooling is exhausted through an electrostatic cleaning process before exiting to a central exhaust system.

An industrial computer running Rockwell Software® FactoryTalk® Historian and FactoryTalk View can be used for data collection and real-time visualization of the technological process data. In some cases a single computer acting as a cell controller can monitor multiple wire saws as they process the silicon blocks. This allows analysis of data from one machine to the next from a single location. Production reports with specific process data can be generated. OEE calculations and reports can also be generated using additional modules included in the FactoryTalk Integrated Production and Performance Suite (e.g. FactoryTalk VantagePoint and FactoryTalk Metrics).

Advanced process control capabilities will become increasingly important as the wafer thickness is reduced and thinner wires are used to cut the silicon ingots. APC offerings from Rockwell Automation can help OEMs tighten control variations and optimize the cutting process.

Typical Architecture

Wafer Slicing Equipment



Rockwell Automation solutions deliver improved production capabilities and reduced 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.

Power, Control and Information Solutions Headquarters

Americas: Rockwell Automation, 1201 South Second Street, Milwaukee, WI 53204 USA, Tel: (1) 414.382.2000, Fax: (1) 414.382.4444

Europe/Middle East/Africa: Rockwell Automation, Vorstlaan/Boulevard du Souverain 36, 1170 Brussels, Belgium, Tel: (32) 2 663 0600, Fax: (32) 2 663 0640

Asia Pacific: Rockwell Automation, Level 14, Core F, Cyberport 3, 100 Cyberport Road, Hong Kong, Tel: (852) 2887 4788, Fax: (852) 2508 1846

Publication OEM-AP061A-EN-P – August 2009