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Operator control and monitoring in photovoltaic production

Throughout the entire manufacturing chain – from silicon to solar silicon, then on to solar cells and finally solar modules – highly automated processes play a key role. They are essential to meet the exacting quality requirements, such as consistently high efficiency of the solar cells or a high production yield. A high level of automation additionally serves to protect the operator against aggressive or otherwise dangerous chemical and physical processes, as well as to shield the production process from the human operator as a potential source of contamination. Complex controllers with local operator and display panels for visualization and interaction are used to control and monitor all process steps.

The requirements specified for the operator control and monitoring equipment are as diverse as the individual steps in the process chain. They range from simple display units to industrial monitors for process visualization in a stainless steel housing with a glass faceplate, built-in membrane keyboard, joystick mouse, and integrated buttons and indicator lamps for harsh industrial environments.

The operator and display panels must be designed for use in strong electromagnetic fields in the vicinity of induction furnaces, in the acid vapors that occur in the production of silicon, and under clean room conditions. This presupposes resistance to a wide variety of chemicals as well as – for some applications – explosion protection approval for Zone 1 or Zone 2 in the solar silicon and solar cell production steps. Finally, control components suitable for clean room environments are necessary to make the solar modules – along with Ex-compatible operator panels, for instance to manufacture the laminating films or protect the solar cells inside the solar modules.

Today, several possible technologies exist for manufacturing solar cells. They are based on different semiconductor materials and production processes. Thin film technology is becoming increasingly established as the method of choice. Inspired by the semiconductor techniques familiar from microelectronics, which are based on silicon single crystals or polycrystalline silicon, it was developed using other semiconductor materials.

The first solar cells were cut out from high-purity silicon single crystal wafers. They achieved high efficiencies of around 20% but entailed very high costs for production, energy, and apparatus. The present second generation of polysilicon solar cells is cheaper to manufacture, and in the meantime its efficiency is likewise close to 20%.

The main requirements specified for the operator panels necessary for the production of high-purity silicon single crystal ingots – either using the Czochralsky method or by zone melting in an induction furnace for wafers with a maximum diameter of 30 centimeters – are resistance to the chemicals and cleaning agents employed in the process as well as mechanical resistance in the complex production environment. The monitors are therefore provided with hard-wearing stainless steel housings as well as short-stroke membrane keyboards made of durable polyester and a touchpad or joystick for controlling the mouse pointer. In addition, these production steps are often classified as Zone 1 or Zone 2 hazardous areas. Excellent electromagnetic robustness is a further precondition in the vicinity of the induction furnaces, though this is not generally a problem thanks to modern liquid crystal displays and suitable shielding measures.

Either CVD (chemical vapor deposition) reactors, in which silicon from the vapor phase is deposited on a high-purity silicon rod, or an alternative process are used to produce solar silicon on the basis of polysilicon. Once again, good resistance to chemicals and robustness to electromagnetic fields are top priorities for the operator panels. In the case of CVD methods, they also have to be resistant to hydrochloric acid because on the one hand this is one of the process reagents and on the other, it is required to obtain the reaction gas (e.g. trichlorosilane, HSiCL3 + H2 $\rightarrow$ Si + 3 HCL). In the long term, hydrochloric acid also corrodes stainless steel classes 1.4301 (304) and 1.4404 (316L). The housings of the operator panels and monitors used here are provided with an additional coating (e.g. powder) for this reason.

If the future solar cells are normally cut out of the wafers as squares, they must additionally be provided with transparent printed conductors, for instance, and an antireflective surface coating (usually shimmering blue or black) in a series of further process steps in order to improve their efficiency. All of these chemical and physical process steps take place under clean room – and in some cases also Ex – conditions. The operator control and display panels must consequently be designed, in particular, to ensure minimal material abrasion (including corrosion), good clean ability, and eligibility for Zone 1 or Zone 2 explosion protection approval.

When solar cells are manufactured in thin film technology, a very thin film of semi conductive material is deposited on a substrate. This can be amorphous (moncrystalline) silicon, combinations of III-V, II-VI semiconductors, or mixtures of extremely diverse materials. The costs for these materials, the production process, and the necessary apparatus are lower than with thick film silicon cells. Glass is often chosen as the substrate for depositing the semi conductive layer, though metals and meanwhile organic films are also used. Improved efficiencies of more than 15% in large-scale production are expected to become a reality in the not-too-distant future (e.g. copper-indium-gallium-diselenide based thin film cells). The size and format of thin film solar cells can be adjusted within a wide window. Rugged operator and display panels in stainless steel housings are used for all of these production processes as for the necessary automation equipment, frequently under clean room and Ex conditions.

The finished solar modules are subsequently assembled from the solar cells. The individual cells are sealed for this purpose with special UV-resistant films that are translucent in the required spectrum to achieve sturdy, weatherproof modules. Whereas the special films are sometimes manufactured under Ex conditions, the modules themselves are usually assembled under conditions corresponding to a low clean room class. The requirements specified for the operator panels as a result of these production steps are certification for use in Zone 1 or Zone 2 hazardous areas and suitability for clean room applications, plus of course ease of cleaning.

All of these very diverse requirements for the operator control and monitoring equipment used in automated photovoltaic production – from the manufacture of the basic chemicals through silicon processing and the production of the solar cells to the assembly of the solar modules – are fulfilled by the remote monitors and panel PCs in the Pepperl+Fuchs VisuNet family. With their stainless steel housing, suitability for clean room environments, optional Ex compatibility, chemically resistant materials, easy-to-clean design, special surfaces, and a wide range of functional and installation options, the VisuNet devices have for several years represented an ideal control solution for photovoltaic production.

About Pepperl+Fuchs

Pepperl+Fuchs is a leading developer and manufacturer of electronic sensors and components for the global automation market. For more than 60 years, our continuous innovation, high quality products, and steady growth has guaranteed us continued success.

One Company – Two Divisions

Pepperl+Fuchs – PROTECTING YOUR PROCESS

The **Process Automation Division** is a market leader in intrinsically safe explosion protection. We offer comprehensive, application-oriented system solutions, including customer-specific control cabinet solutions for the process industry. A large portfolio of components is available from our various product lines: isolated barriers, fieldbus infrastructure solutions, remote I/O systems, HART interface solutions, level measurement devices, purge and pressurization systems, industrial monitors and HMI solutions, power supplies, separator alarm systems for oil and petrol separators, signaling equipment, lighting as well as emergency shutdown equipment and accessories.

Pepperl+Fuchs – SENSING YOUR NEEDS

With the invention of the inductive proximity sensor in 1958, the company set an important milestone in the development of automation technology. Under the motto “Sensing your needs”, customers benefit from tailor-made sensor solutions for **factory automation.** The main target markets of the factory automation are machine and plant construction, the automotive industry, storage and material handling, printing and paper industry, packaging technology, process equipment, door, gate and elevator construction, mobile equipment, renewable energies.

The division offers a wide product range of industrial sensors whether it’s inductive, photoelectric or ultrasonic sensors, rotary encoders, identification systems, barcodes, code readers for data-matrix-codes and vision sensors.

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Fig. 1: VisuNet Remote Monitors and PC will be used for process steps in hazardous atmosphere

Fig. 2: Product line VisuNet GMP: resistant against used chemicals and easy to clean