Seamless Integrated Automation Using the MKS Automation Platform

PROBLEM

Throughput, quality and cost have always been key technology and decision drivers in industrial automation and manufacturing. Today's customers have complex automation solution requirements: scalability, expandability into numerous environments, seamless integration, and fast delivery.

In many industrial process tools subsystem equipment control is often configured in a piecemeal manner, using independent, tiered control schemes. Typically, each subsystem controls only a fraction of the system's devices resulting in concomitant issues of redundancy and cost. Often the subsystem controllers cannot easily communicate with each other, nor is it a simple task to integrate their operation with a tool's PC/Host. Furthermore, tiered systems typically provide only minimal capabilities for data logging, a critical drawback for advanced process control protocols. Independent, tiered equipment control systems are frequently inefficient and require significant manual interaction negatively impacting both cost and yield.

BACKGROUND

System controls used in many manufacturing environments incorporate a number of independent subsystems that perform the materials handling, processing, control, sensing, and analysis functions throughout the overall manufacturing process. Optimized operation in the tool is most easily achieved when communication and control for all of the subsystems are tightly synchronized. However, the subsystems may be supplied by more than one original equipment manufacturer (OEM), making optimization a challenge.

By way of example, consider the semiconductor wafer processing system shown in Figure 1. This tool incorporates independent equipment and control nodes for vacuum and pressure, gas flow, process chamber and vacuum line temperatures, plasma power supply, automated wafer handling and for process data collection, communication and analysis.

This single tool incorporates more than a dozen independent subsystems. Similar variety and numbers of subsystems are
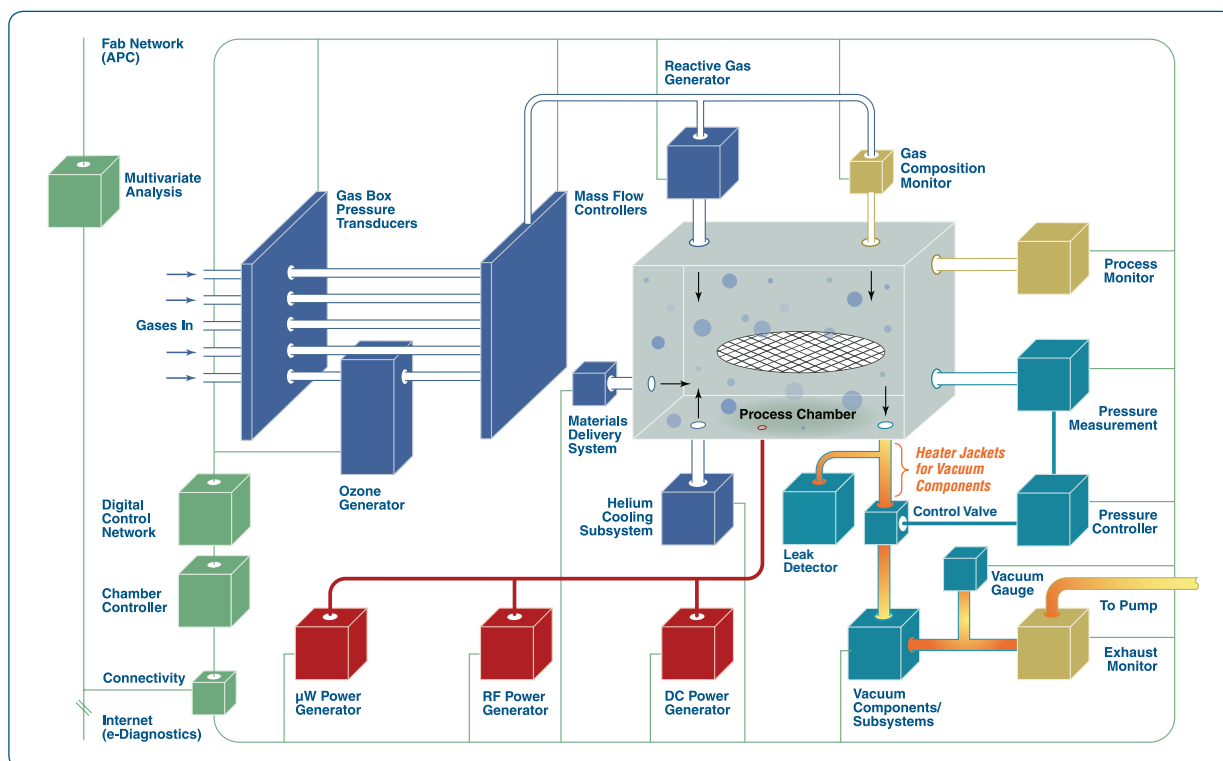

Figure 1. Generic semiconductor wafer processing tool illustrating different subsystems required for operation
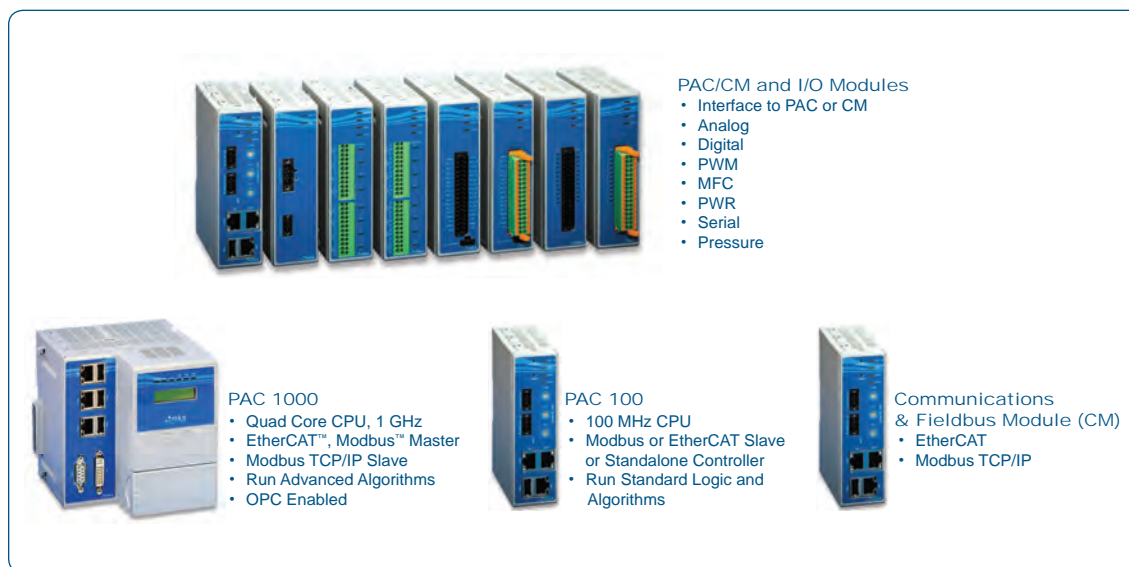
Figure 2. MKS Automation Platform Modular Components

found in process tools employed in the manufacture of flat panel displays, UHV coatings, and solar energy products. Analogous equipment configurations also exist in the process tools in many other manufacturing environments, ranging from chemical processing to retail product manufacturing. Safe and effective operation of networks having multiple control modules or nodes that maintain semi-autonomous local control over subsystem functions can be extremely challenging. Many approaches suffer from poor accuracy and precision arising from latency delays and determinism/timing challenges at both the local device level, and the centralized tool control level. Additionally, the time and cost required for the implementation of effective safety protocols in network architecture and local control modules are negatively impacted by this complex architecture.

Modern process tools are further complicated by the fact that advanced tool protocols do not function in a reactive mode, but rather proactively control multiple local control nodes to achieve intelligent and programmable control of the entire tool and process. Proactive operating philosophies couple early fault detection and classification with better process understanding, and integrated control and automation functions to improve efficiency and safety, and to lower tool operation costs. Proactive control can facilitate reductions in the process environmental impact, simplifying the efforts

needed to comply with government regulations, and improve product performance and reliability.

Precise, well-synchronized and programmable control of different local modules is a prerequisite for proactive process control. Command information and sensor data needed for synchronized control have to be transferred between master and subsystem controllers in real-time or near real-time. Real-time sensor data is needed by the safety interlock system should a system failure occur since many process tools employ toxic, corrosive and pyrophoric chemicals, high temperatures and high electrical voltages. Finally, with the modular architecture of most advanced process tools, all of this control and communication must be duplicated for multiple process modules.

Network/node-based control can be managed by using a single, centralized automation platform capable of complete tool, process and distributed control. This approach lessens tool complexity by reducing in the number of microprocessor cores and operating systems employed for control. This centralized control can be fast and deterministic while being simultaneously programmable, safe and secure. Centralized controllers for system tools can also significantly lower the cost of the control architecture as compared with existing approaches.
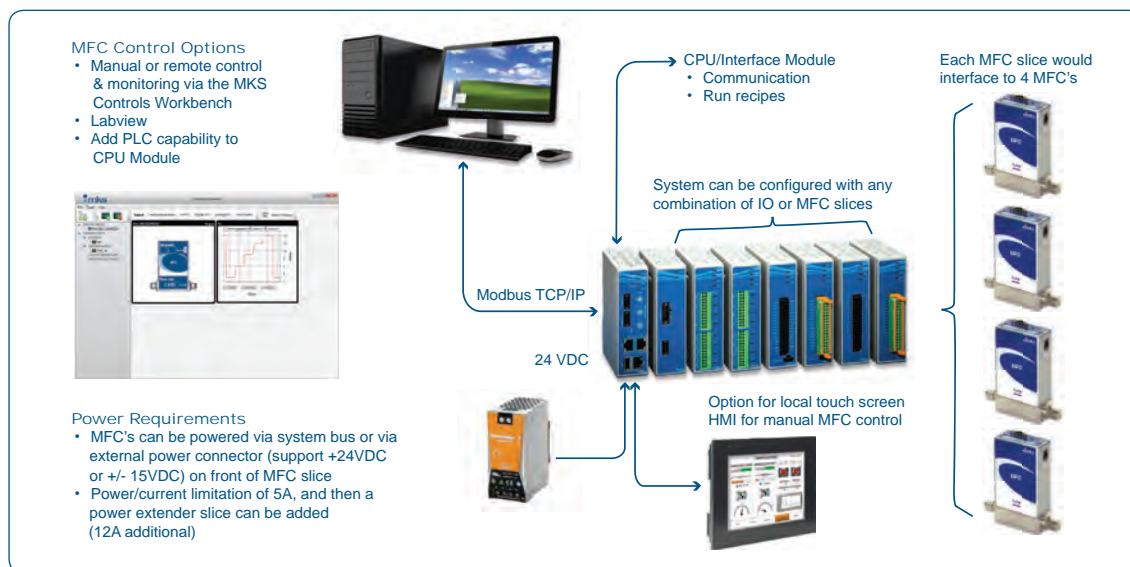
Figure 3. MKS Automation Platform Configuration Overview

THE SOLUTION

MKS Automation Platform

MKS has introduced the Automation Platform solution to seamlessly interface MKS products for comprehensive control that improves process tool efficiencies, dramatically lowers the total ownership cost compared to standard off-the shelf solutions, and increases equipment utilization in new and existing tools. The Automation Platform is a fully programmable, open standard, modular solution that is both flexible and scalable. It merges the characteristics of programmable logic controllers (PLCs) with those of industrial personal computers (IPCs) to solve many of the problems encountered in network/node based equipment control. Providing greater performance than either PLCs or IPCs in a more compact, customizable, and cost effective package, the MKS Automation Platform enables localized and high speed I/O control with local logic. It can be implemented in a modular, DIN rail mountable plastic enclosure for a single tool location or as an intelligent distributed node on a manufacturing line. The Automation Platform has a library of process routine templates and function blocks that facilitate faster implementation. Combined, these features result in faster installations and shorter downtimes for the process tool,

ultimately leading to reduced time to market. Customers can leverage the MKS Automation Platform to integrate a fully automated solution of instruments and devices in processes that require precise monitoring and control. These include programmability with MIMO control, vacuum processes, environmental monitoring, LEDs, MOCVD, life sciences, analytical instrumentation, safety interlocks, plastics and ceramics manufacturing, packaging, biopharm, and food and beverage processing.

The modular components of the MKS Automation Platform are shown in Figure 2. They include the PAC 1000 and the PAC 100 programmable automation controllers, communications and fieldbus module (CM) (with four I/O modules), and an application-specific unit incorporating a CM (or PAC 100) and seven MKS I/O modules. The platform enables direct interfacing to a variety of MKS mass flow controllers (MFCs), sensors, actuators, valves, and other devices using standard fieldbus protocols such as EtherCAT™, Ethernet/IP™, and Profinet. (Non-Ethernet fieldbuses such as DeviceNet™ and Profibus, and communication protocols such as Modbus and TCP/IP are also supported.) The Automation platform can be interfaced with a Labview application or routines and logic can be developed directly on the PAC 1000 & PAC 100 via an IEC 61131-3 compliant programming software, supporting the following
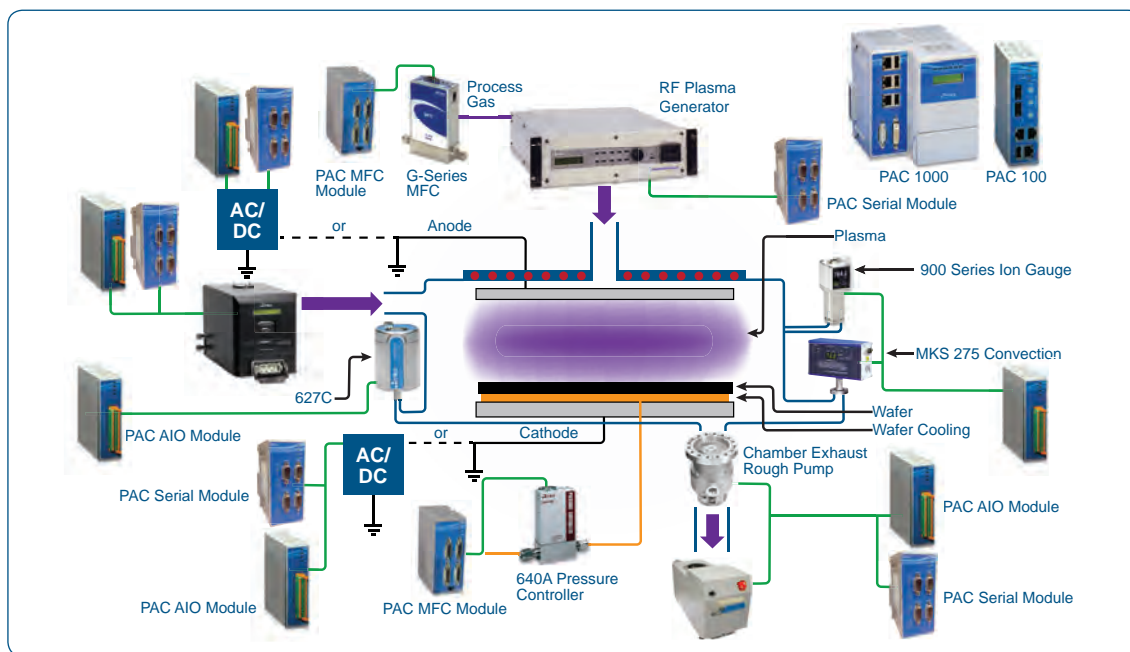
Figure 4. Semiconductor wafer processing system with the MKS Automation Platform for subsystem control

programming languages:

- Ladder logic
- Structured text
- Function block diagrams
- Instruction list
- Sequential function charts

The PAC 1000 and PAC 100 enable fully programmable control for MKS and other manufacturer's products. The PAC integrates and automates the sensors and devices resident in a process tool, enabling faster installations and reduced tool downtimes. The PAC interfaces to MKS' communications and fieldbus coupler module to effectively integrate serial devices and sensors (RS232 and RS485), MFCs, Baratron® capacitance manometers, Analog I/O (±5V, 0-5V, ±10V, 0-10V, 0-20mA, 4-20mA), discrete I/O valves (0-24V), RTD/ thermocouples, and heater outputs. Pre-existing libraries of function blocks are available for MKS products to facilitate process logic development. MKS integration services provide assistance in recipe and logic development, integration and training.

In addition to the programming environment, Controls Workbench (CWB) software, provided with the MKS Automation Platform, enables access, monitoring and remote control of each MKS controller by a single PC. The CWB software can be used to create custom dashboards that provide convenient and user-friendly GUIs for configuration, process monitoring and charting, tuning, and advanced control options. Figure 3 shows an overview of a typical implementation of the Automation Platform, in this case controlling four MFCs. The platform can be configured to support the SenseLink™ QM application for real-time multivariate analytics (from MKS Data Analytics Solutions) that support proactive control for prediction and containment of process defects. The platform leverages MKS Data Analytics' experience in Design of Experiments (DoE) through MODDE® software and process optimization, and applies it to control and automation. Additionally, the platform can be configured to support a number of advanced control algorithms from either MKS or third parties. One example is the use of a Model Based Control (MBC) approach to provide significantly improved temperature control compared to common PID control.

CUSTOMER SOLUTIONS

Semiconductor Process Tool Example

Figure 4 shows a schematic drawing of a generic semiconductor wafer processing tool, similar to the one described in Figure 1. This schematic shows those areas where MKS Automation and Control solutions can be used to integrate and synchronize equipment control within the tool. A PAC 1000 or 100 can be interfaced to a variety of MKS I/O modules to integrate and synchronize control of gas flow, plasma power, and process pressure sensing and control.

Ceramic Manufacturing

Figure 5 shows a very large hot zone furnace that is employed in ceramics manufacturing. This particular system is used for multi-step depositions of different functional coatings on the ceramic substrate surface. In order to avoid risk of contamination, these processes need to be performed in sequential manner, while keeping the parts in the furnace.

The customer had individual controllers or software applications which were used to control each device, component or subsystem manually. The requirement was to centralize into one system and automate the temperature control, vacuum and pressure sensing and control, and gas flow control for the sequential recipes used for depositing interface coatings, passivation layers and chemical vapor infiltration (CVI) matrices.

Control of the furnace (temperature), rough pump, heaters, throttle valve, pressure sensing Baratron capacitance manometers, solenoid valves, and six mass flow controllers required full automation. Following the adoption of the MKS Automation Platform, the customer experienced a number of significant technical and economic benefits in system operation
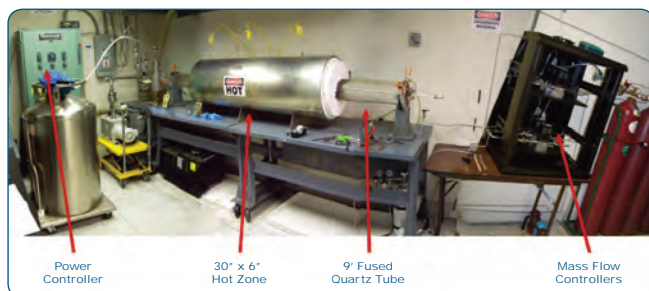

Figure 5. MKS Automation Platform for a Ceramic Treatment Application

Figure 6. MKS Automation Platform for Gas Mixing Application

including eliminating subsystem manual control, reducing the number of failure points simplifying troubleshooting, and significant cost savings from reducing the number of control systems.

Gas Mixing

A customer needed to automate the control of a gas manifold delivery system, interfacing MKS and another manufacturer's MFCs with pressure sensing and control. The customer had four independent controllers involved in this single gas delivery system. An Automation Platform was configured which employed a single MKS CM, three MFC I/O modules, and the CWB for remote process control and monitoring.

Implementation of the MKS Automation Platform solution shown in Figure 6 eliminated the costs and redundancies associated with previous use of four control systems. Estimated cost saving to the customer was $10,000. Similar application of MKS automation products in more complex gas mixing applications are expected to yield higher savings relative with the level of reduction of complexity.

Figure 7. MKS Automation Platform for UHV Coatings Application

UHV Coatings

A customer wished to automate an Ultra High Vacuum (UHV) coating process. The automation scheme needed to be modular and seamlessly interface with other MKS instruments in the facility.

MKS supplied the automation solution shown in Figure 7 which consisted of a PAC 1000, CM and I/O modules along with a Human Machine Interface (HMI) interfaced with Baratron capacitance manometers, an MFC, and a Vacuum Quality Monitor (VQM). This provided the customer with a single-source solution for instrumentation, automation, design services for process recipes, and HMI. This coating process solution can be implemented at other process stations within the facility, reducing operational and maintenance costs, providing faster system installation and qualification, and allowing access to all MKS controllers within the facility via the CWB.

MFC Control Applications

A gas sensor manufacturer required a flexible, programmable and cost effective Ethernet based controller for a large number of MKS MFCs.

MKS provided a solution that employed a PAC 1000 with full programmability and a Modbus TCP/IP master for controlling 16 MFCs (Figure 8). The customer achieved a programmable solution at a total cost of only $1500.

Figure 8. Ethernet-Based MFC Control Solution

CONCLUSION

The MKS Automation Platform is a comprehensive, flexible and scalable solution for automation control that improves operational and productivity efficiencies in a wide variety of processing environments. The platform enables synchronized subsystem connectivity to both MKS and other manufacturer's components. MKS subsystems and instrumentation include the following:

• Mass Flow Controllers	• Heater Jackets
• MODDE® for DOE	• SIMCA® for MVA
• RF & DC Power Generators	• Vacuum Quality Monitor (VQM)
• Residual Gas Analyzers	• Optical Gas Analyzers
• Remote Plasma Sources	• Microwave Generators

• Direct Pressure Gauges
  – Baratron® Capacitance Manometers
	• Indirect Pressure Gauges
	  – Granville-Phillips® Controllers, Modules and Gauges

The Automation Platform employs MKS Controls Workbench software for configuration, process monitoring, tuning, and data storage in a Host/PC environment with capability for local touchscreen HMI for manual control. MKS integration services assist in recipe and logic development, integration and training. In addition, MKS' Senselink QM quality prediction system provides an entire solution for process monitoring and part quality prediction utilizing multivariate analysis (MVA) technology from MKS Data Analytics.

The advanced control and interfacing features of the MKS Automation Platform provide users with significant cost, quality and time to market advantages.

For more information on MKS Instruments Automation Platform, link to our web site: http://www.mksinst.com/product/product.aspx?productID=1488

For a general catalog of MKS Products, follow this link: http://www.mksinst.com/index.aspx