USABILITY IMPROVEMENT WITH SAFETY NETWORK AND APPLICATION TO SEMICONDUCTOR MANUFACTURING EQUIPMENT

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Abstract

In manufacturing industries using robots and various machines, systems have to employ many safety components to comply with international standards such as ISO 12100, IEC 60204, and related standards. Emergency stop switches and door interlock safety switches are required so that, in case of an emergency, a hazard can be shut down. Since failure of control systems should not affect safety control systems, these systems were designed and installed separately. Open network technology, which greatly reduces wiring and maintenance cost, could not be connected to safety equipment. Recent technology has allowed for development of network systems that can be used with safety control components. We have examined these safety networks and established a safety control system by implementing AS-Interface Safety at Work (AS-i SAW) [1] to the semiconductor manufacturing equipment industry. This paper reports on the performance of a new safety control system in which general control and safety control are compatible.

Introduction

In factory automation (FA) and process automation (PA) areas, where attention is mostly paid to the enhancement of operation efficiency, the importance of an operators' safety is becoming more and more important [2, 3]. Because the number of industrial accidents that cause damage to both machines and operators is increasing, international standards such as ISO 12100 (Safety of machinery - Basic concepts, general principles for design) and IEC 60204 (Safety of machinery - Electrical equipment of industrial machines) were issued to raise the awareness of the importance of safety. Semiconductor manufacturing equipment and other automatic assembly lines using robots are, in order to ensure safety, required to

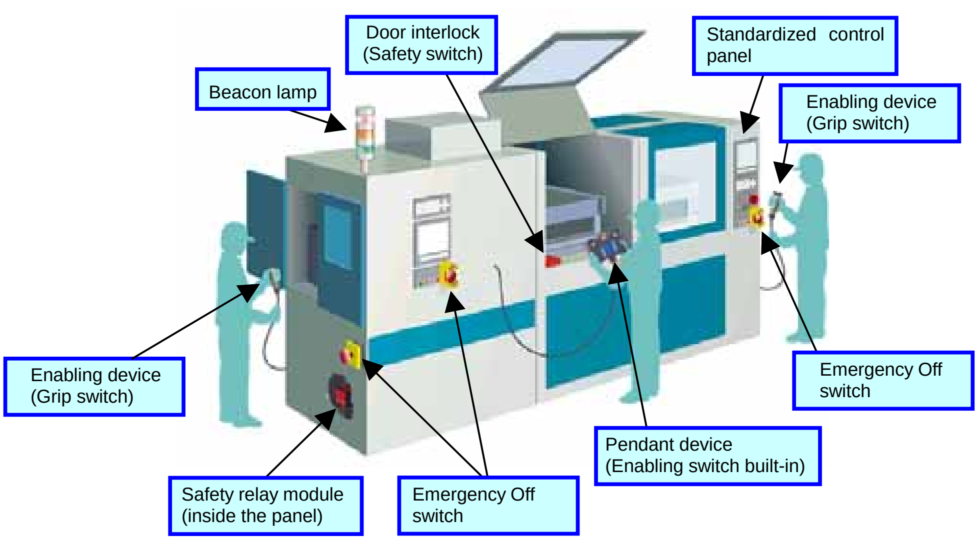


Figure 1. Example of the Semiconductor Manufacturing Equipment

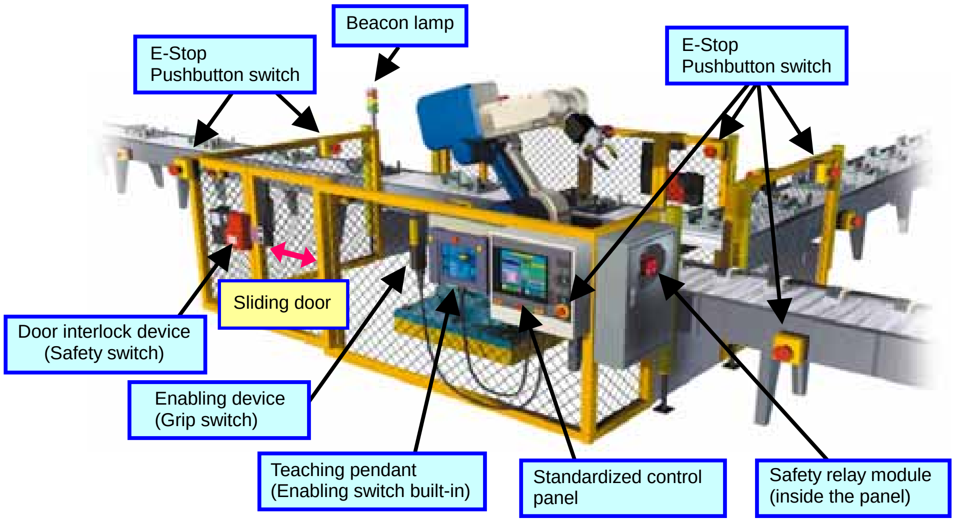


Figure 2. Model of the Manufacturing system with Robots

mount emergency stop switches, safety switches, and a number of other safety components as shown in figure 1 and 2. A system of safety components is needed to be constructed separately from standard control systems, to maintain performance, and therefore the design, manufacturing, and maintenance requires a great deal of labor. Therefore improvements in operational efficiency and safety have long been considered mutually incompatible. As a result, improving the usability of a safety system has been a major issue that has faced the manufacturing industry.

Manufacturing industries around the world are gradually introducing safety networks in which safety components such as emergency stop switches and safety switches can be connected to a network, complying with IEC 61508 (Functional safety of electrical/electronic/programmable electronic safety-related systems) [4]. In this paper, we report an overview of the benefits of safety networks, and also provide an analysis of improvement when applying AS-i SAW to semiconductor manufacturing equipment. [5]

Safety System Establishment in FA

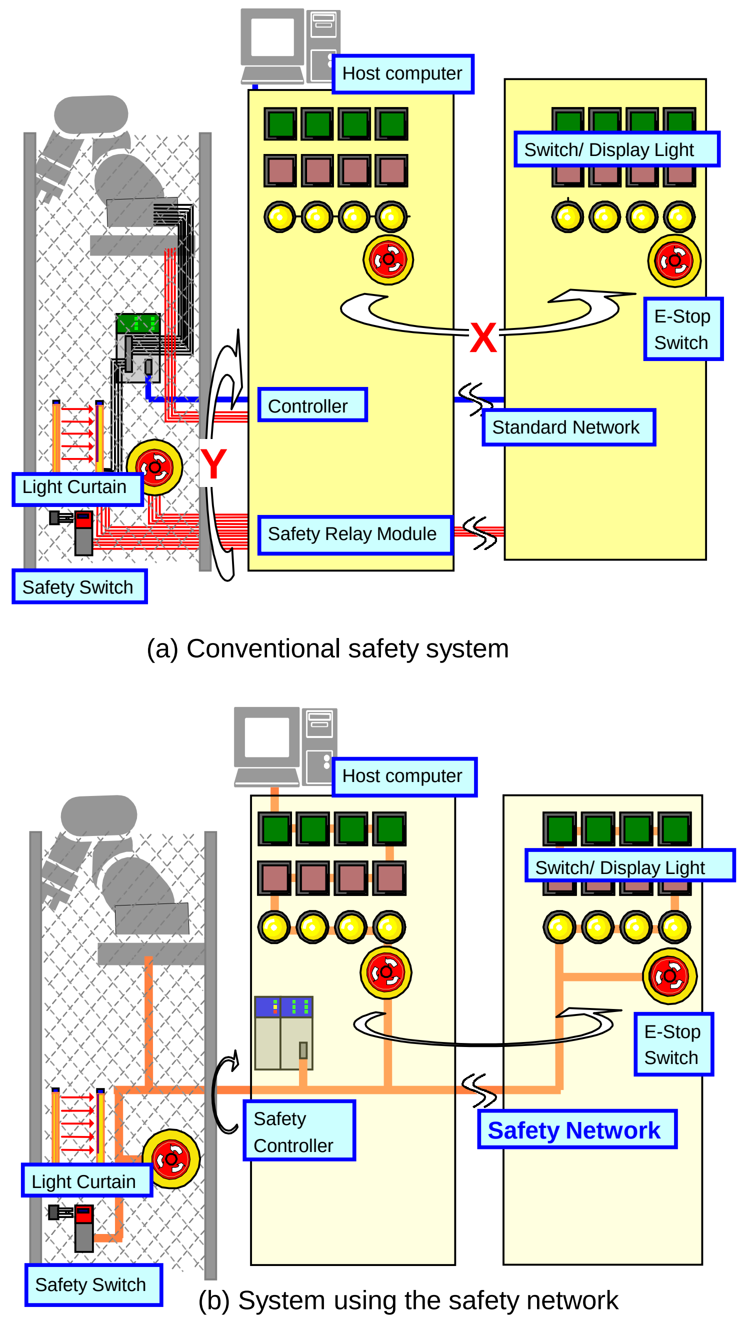
Figure 3 shows an automatic assembly line using robots, in which we compare a conventional system shown in Figure 3 (a) and networked safety system shown in Figure 3 (b). In the conventional system, the control system and safety system are structured separately. The control system consists of pushbuttons, pilot lights and other I/O devices, while the safety system is comprised of safety components such as emergency stop switches, safety switches, and light curtains. A safety relay module is used to shut the power to hazardous sources such as robots and motors. A separate structure is intended to ensure safety, because the failure of control system does not affect the operation of the safety system. In the control system of the conventional system, PLCS, pushbuttons, and pilot lights are hard-wired, requiring as many as 30 wires to connect 16 pushbuttons and 8 pilot lights shown with an “X”. In a safety system, safety relay modules, emergency stop switches, safety switches and light curtains are hard-wired as well, but require only 17 wires as shown with a “Y”. Wiring a control system necessitates a great deal of labor for the wiring itself, checking the wiring, and maintenance, thereby resulting in increased costs.

In factory automation (FA), process automation (PA), and building automation (BA), the number of pushbuttons, illuminated pushbuttons, pilot lights and other low-level components surpass that of other levels. Although components require complicated wiring, little attention has been paid to their usability related to manufacturers and maintenance operators. To solve this problem, we have developed a wire-saving network, SwitchNet, which exhibits excellent performance for manufacturers and maintenance operators. With SwitchNet, wiring work can be simplified without impairing operability [6-8].

Figure 4 shows a comparison between conventional wiring and SwitchNet wiring. Figure 4 (a) shows an operational control panel, on which 40 control units such as pushbuttons and pilot lights are installed. Figure 4 (b) shows the back of the same control panel, which is structured with conventional wiring, while the control panel shown in Figure 4 (c) is designed with using SwitchNet. As the figures show, wiring with SwitchNet is much simpler and organized, proving that SwitchNet provides superior connection methods and reduced installation time, costs, and area. The network technology that achieved both wire- and labor-saving, as well as an improvement in safety technology, made it possible to connect control equipment and safety equipment in one network. This is safety network technology.

Figure 3 (b) shows a system concept in which a safety network is installed.. As illustrated, control-related components (pushbuttons, pilot lights) and safety-related components (emergency stop switches, safety switches) are connected to a safety controller without any constraints. This system can also be connected to a host computer seamlessly, and high-speed data communication (sending an enormous amount of data) is achieved over just one network. With this new technology, the entire system including both control and safety signals can reduce wiring, labor, costs, and also improve in usability.

As manufacturing plants are increasingly evolving, along with information technology and remote control systems, requirements for open-networking of control components and safety components is becoming greater, and various safety networks have been developed in many countries. Table 1 shows examples of safety networks, which comply with IEC 61508 and satisfy high safety integrity level (SIL) by reducing failure rates and introducing safety life cycles. AS-i SAW is one of the major networks in the world of this type.



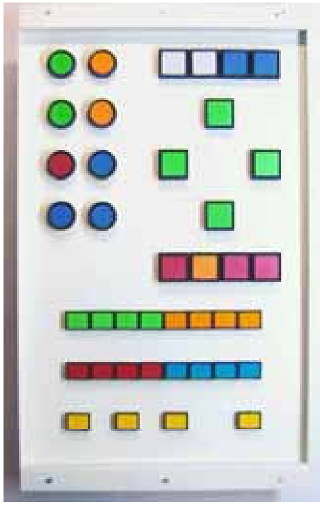
(a) Conventional safety system

(b) System using the safety network

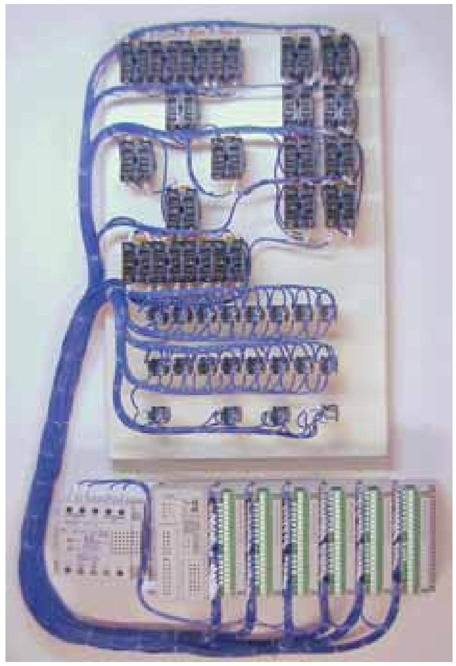
Figure 3. Safety Network Systems

Features of AS-Interface Safety at Work

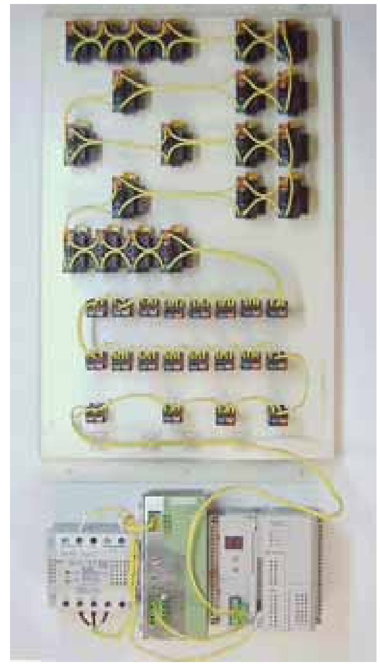
For semiconductor manufacturing equipment to comply with international standards such as ISO 12100, IEC 60204-1, and also SEMI standards (which offer guidelines for the semiconductor industry), it needs to undergo a risk assessment. This risk assessment is not only for normal operations, but is also on system setup, teaching, system change-over, and maintenance. Many safety components, as shown in Figure 1, must be installed on semiconductor manufacturing equipment. For example, emergency OFF (EMO) switches and door interlock safety switches are required to be installed on the system so that in case of an emergency, a hazard can be shut down. We have provided a Human Machine Interface (HMI) environment with the necessary safety components [9-11].



(a) Operation control panel



(b) Field-end components connected by the conventional wiring



(c) Field-end components connected by the wiring of SwitchNet

Figure 4. Comparison between the conventional wiring and the wiring of SwitchNet

AS-i SAW is one of the most popular open networks in Japan, North America and Europe, and was developed to connect the safety components to an AS-Interface network, which complies with IEC 62026-2. The AS-i SAW achieves an integration of control signals and safety signals [12], and has been approved by TÜV (Technischer Ürberwachungs Verein), a third-party certification organization, to be in compliance with IEC 61508-1 to 7, SIL 3, and the highest safety category 4 of EN954-1 [13].

Table1. Comparison of Safety Networks

Safety-related field network	AS-i Safety at work	CC-Link Safety	DeviceNet Safety	INTERBUS Safety	ProfiSafe	SafetyBUS p
Consortium	AS-International Association	CLPA	ODVA	INTERBUS Club	ProfiBus International	SafetyBUS p Club
Based field network	AS-Interface	CC-Link	DeviceNet	INTERBUS	ProfiBus	–
Original developer	AS-International Association	Mitsubishi	Omron, Allen Bradley, and Sick	Phoenix Contact	Siemens	Pilz
Topology	master/slave	master/slave	master/slave	master/slave	master/slave	multi-master
Maximum number of slaves	31 nodes	64 nodes	64 nodes	512 nodes	122 nodes	64 nodes
Speed (bit rate)	167kbps	Max.10 Mbps	500 kbps	500 kbps	Max.12 Mbps	Max.500 kbps
Maximum cable length	100m (167kbps) 300m (167kbps with Repeaters)	100m (10Mbps) 160m (5Mbps) 400m (2.5Mbps) 900m (625kbps) 1200m (156kbps)	500m (125kbps) 250m (250kbps) 100m (500kbps)	400m (between slaves) 12.8km (total length)	100m (12Mbps) 200m (1.5Mbps) 1000m (187kbps)	100m (500kbps) 500m (125 kbps) 1000m (50kbps) 3000m (20kbps)
Control field network and safety-related field network on one topology	Yes	Yes	Yes	Yes	Yes	No

Note: Networks are listed in alphabetical order.

As Figure 5 shows, AS-i SAW makes it possible to establish a safety network by simply connecting the general control system (containing an AS-Interface master, standard slaves, SwitchNet, AS-i power supply), the safety input component (safety slave), and safety output and network monitoring component (safety monitor) to an existing AS-Interface network. Wiring of components is easy and simple, by just connecting to the existing AS-I cable. This process requires little labor time. Wiring SwitchNet can also be completed easily just by connecting a branch connector to the AS-i cable and connecting two wires in series. The operating condition of a safety output is programmed by PC software and the data can be downloaded to a safety monitor. When compared to the conventional development of a logic circuit by hardwiring, the savings in time and labor become evident. Moreover, a safety system can be configured to suit various requirements and operating conditions, providing more flexibility

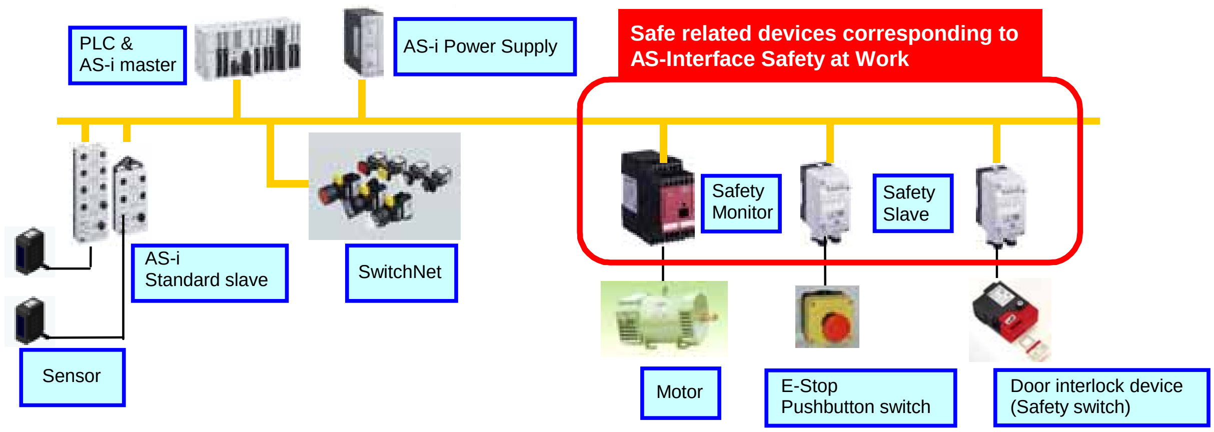


Figure 5. AS-Interface Safety at Work Basic Configuration

Application to Semiconductor Manufacturing Equipment

Figure 6 shows a wafer etching system, a type of semiconductor manufacturing equipment. Cutting-edge safety technologies have been introduced to this system to achieve inherent safety, complying with various safety standards such as SEMI-S2. The usage of AS-i SAW has greatly contributed to the achievement of a high level of safety.

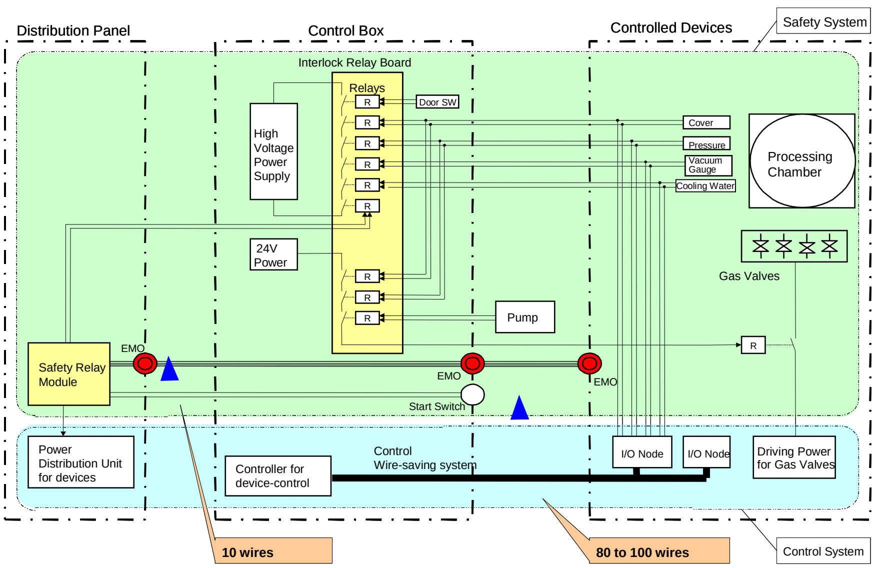
Comparison of conventional systems and AS-i SAW systems

Figure 7 shows the comparison of safety-related control systems, one conventionally configured and the other using AS-i SAW. In the conventional system, shown in figure 7 (a-1), the safety system and the control system are separately designed. The safety system, as shown in figure 7 (a-2), is configured using interlock relays and is hardwired. In the control system, a network has been introduced to centrally control the controllers achieving some degree of wire saving. However, the safety system involves wiring over 100 points, requiring a great deal of labor and cost. Because the system is hardwired and designed using a proprietary relay interlock board, considerable amount of labor and expenses are required for system modification and improvement or when debugging the system at start-up, or system changeover

Figure 6. Wafer Etching System

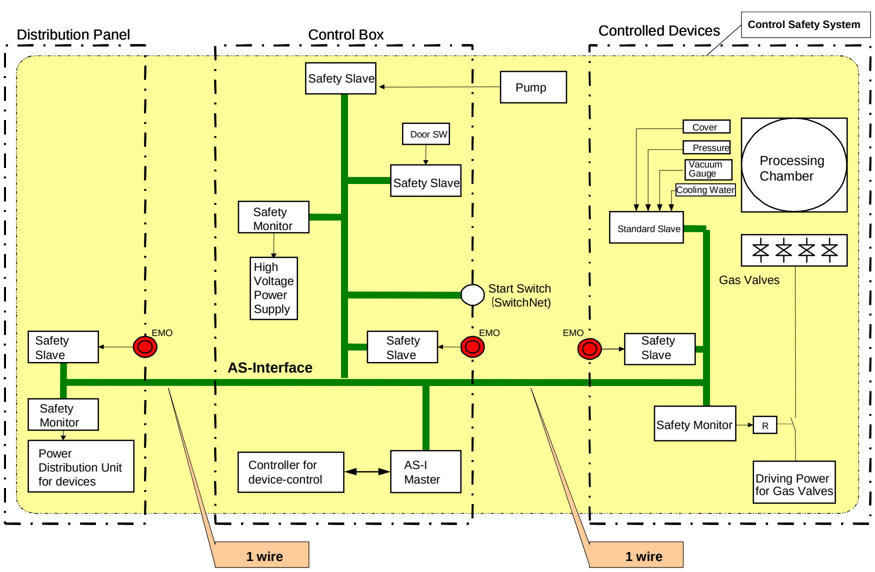
to specific users' request. Furthermore, labor and expenses are also necessary when applying for certification by a third-party organization.

In the system employing the AS-i SAW, shown in figure 7 (b-1), the safety system is configured using only one AS-i cable, and the control system is also simply designed with SwitchNet connected to the same network, achieving wire-savings and improved usability [14]. In addition, while the conventional safety system needed a proprietary interlock relay board (requiring labor and expense for system development and modification), using AS-i SAW, which is approved for safety certification, greatly simplifies the process of basic designing and certification procedures for international standards.



(a-1) Conventional system configuration

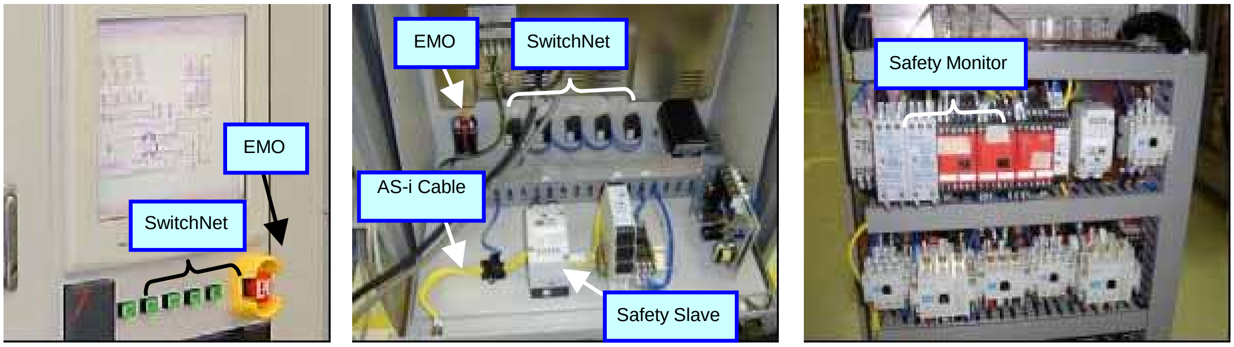
(a-2) Inside control panel



(b-1) System configuration using AS-Interface Safety at Work

(b-2) Inside control panel

Figure 7. System Comparison between the (a) Conventional System and (b) AS-Interface Safety at Work System Control System Unit



(a) Operation Panel (b) The Inside of Operation Panel (c) Power Supply of System

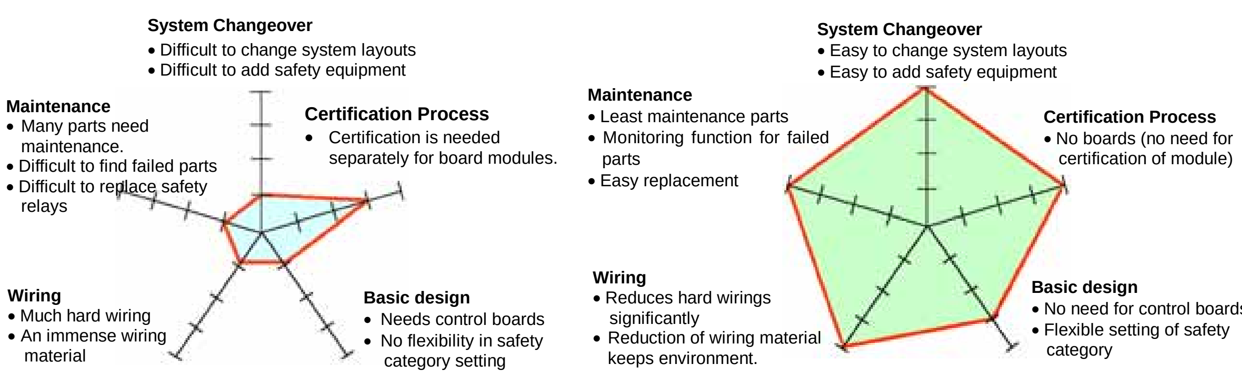
Figure 8. Operation Panel and Internal Unit of Wafer Etching System

The system using AS-i SAW consists of a control box, controlled devices, a distribution panel, and an operation panel. The operation panel, shown in figure 8 (a), houses the operation display, SwitchNet components, and an emergency stop switch (EMO). In the operation panel, the control-related SwitchNet components and safety-related emergency stop switch are connected via a safety slave as shown in figure 8 (b). The network inside the operation panel is configured simply with an AS-i cable and a two-wire parallel cable. In the power supply box, shown in figure 8 (c), a safety monitor is installed in the center, which works in conjunction with the emergency stop switch and controls the main power supply. The SwitchNet components on the operation panel control the startup and restarting of the devices.

<u>Evaluation of AS-i SAW Usability</u>

Figure 9 compares the usability of safety-related control systems, used in semiconductor manufacturing equipment, evaluating on design, production, installation, and maintenance. Figure 9 (a) shows the evaluation of a conventional system, while figure 9 (b) shows the analysis of the system in which AS-i SAW is being used. As clearly illustrated, the safety-related control system with AS-i SAW excels in all evaluation points, proving superiority in basic design, wiring, system changeover, maintenance, and certification process.

Because semiconductor manufacturing equipment is large in size, flexibility and speed are needed in developing and changing systems in order to respond to the users' needs and safety requirements. AS-i SAW provides flexibility to the system by facilitating the processes of increasing and changing of safety slaves, safety monitoring standard slaves, and also software settings. By using AS-i SAW, semiconductor manufacturing equipment has been enhanced in design and usability, and prove to be the highly superior equipment by the use of state-of-the-art safety technology.



(a) Conventional Safety-related Control System (b) New Safety-related Control System using AS-Interface Safety at Work

Figure 9. Usability Comparison of Semiconductor Manufacturing Equipment

Future Research and Development

As the application of AS-i SAW to semiconductor manufacturing equipment has revealed, AS-i SAW is an optimum choice for improvement of usability in aspects of both safety and control. Manufacturing industries around the world are now working hard on critical issues; international standardization, open networks, saving, and safety. An AS-i SAW network system solves all these issues, and achieves integration of information and safety. While the application of AS-i SAW to other machine systems is expected to increase, we are committed to continue research and development of this technology for increased usability.

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