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Review of Role of Electronics in Production and Industrial Engineering

Jeebananda Panda[1], Radhika Dang[2], Satvik Maurya[3], Sirish Oruganti[4]

(Delhi Technological University, Delhi, India)
Email: jpanda@dce.ac.in

Abstract : *This paper explores the recent advances made in the field of Industrial Electronics. With the growth of the consumer market in the 1960s and 1970s, the need for the fast and efficient production of goods and services was needed. With the advent of transistor-based integrated circuits, there was a huge increase in the use of microprocessors and programmable logic devices in the industry in the form of computers and programmable controllers. This thus resulted in the use of these electronic devices for the improvement of speed, volume and rate of industrial production. In this paper, we review technical papers related to Robotics, Factory Automation, Power Electronics, Control and Communication Systems used in the industry and we show some of the recent advances made in these fields.*

Keywords – Industrial Electronics, Industry Standards,Robotics, Factory Automation, Power Electronics, Control Systems, Industrial Communication Systems.

INTRODUCTION

Industrial Electronics became a major field of study during the 1970s because of the increased need for improving productivity of the industry. With time, tools like Computer Aided Manufacturing, microprocessors, Computer Numerical Methods penetrated every facet of industrial application to attain the productivity goals. The application of voice recognition for industrial applications too gained traction [1]. Before this however, in 1969, industrial relay panels were replaced by programmable controllers (PCs) which drastically widened the functions of the relay panels. By 1982, they were being used for the execution of complex mathematical algorithms, data acquisition and storage, report generation, servo motor control, stepping control, diagnosis and troubleshooting [2]. With time, the staggering growth of the use of industrial electronics technologies resulted in the need for standards which could be used throughout the industry. This thus corresponds to one of the functions of the Industrial Electronics Society (IES) of the IEEE. With the introduction of standards, the manufacturing processes became more uniform and conformed with modern safety regulations. With fixed standards, the application of technology to improve productivity thus became more popular. In the past few decades, industrial electronics as a field has grown leaps and bounds and while there are still some areas, which have not been fully explored, the role of electronics in the service, manufacturing industries has grown leaps and bounds. In this paper, we present some of the present advances made in the various fields of industrial electronics.

II. ROBOTICS AND FACTORY AUTOMATION

A. Robotics in the Industry

As mentioned in [3], the paper analysis by IES shows that in all the areas of industrial electronics, the work in robotic standards is not being reported. The entire distribution is shown in table 1.

Area	Number
Robotics	0
Control, sensors and actuators	2
Transportation	5
Industrial Automation	19
Communications	27
Power and Power Electronics	44
Other	10

Table 1: Paper analysis by IES

While the report highlighted that there wasn't any substantial work being done in the robotics field, the reality is quite the opposite. As mentioned in [4], robotic arms have been in industrial use since the 1980s, a time when all kinds of approaches were being explored to improve productivity. With the growth of the computer and electronics industry, the complexity and the role of robotics changed in its industrial applications. As cited in [3], robotics in the future will be ever present in the industry with huge importance in manufacturing. But, with its ever changing roles, its primary purpose will not be for mass production, instead, they will support mass customization in small factories where the production process is short and the products are modular. While this will hold for the future, new advances in the robotic arm technologies for the manufacturing industry and the services industry are plentiful. We proceed by listing some below:

i. Multi Degree of Freedom (multi – DOF) robots:

With the need to make the manufacturing process fast as well as precise, the need arose to make robotic arms which could simulate the human waist, arm, forearm and wrist to make achieve a fair bit of precision as well as speed. The research on the multi – DOF industrial welding robot in [5] using neural networks represents the latest advancements in the robotic technologies for industrial applications.

ii. Robotic Gripper for industrial high speed assembly: Due to the high demand of dexterity, precision and speed in the industrial assembly process, the development of a robot that can grasp large number of parts with the correct postures became very important. In [6], we see the proposal of a novel gripper for industrial applications which can precisely twist and position any object fitting the necessary dimensions.

iii. Robots in the Healthcare Industry: The robots presented in [7], 'CareBot' and 'ReceptionBot' are examples of the huge role robotics has and will get in the services industry. The robotic systems proposed in [7] are highly sophisticated and are capable of modifying their functions autonomously.

Apart from these new developments in the field of robotics, existing technology has been further improved with the use of sophisticated software which further increases the function of robotic systems in the industry, an example being the Natural Interface presented in [8] for the control of an Industrial Hydraulic Arm. This is indicative of the importance robotics has in industrial applications in present times.

B. Factory Automation

The automation of factories refers to the automatic control of various processes and machinery in a factory with the help of various control systems and software systems with minimal human involvement. The need of automation of factories goes hand with the need to increase the speed and rate of production as well as improving the safety standards in the factories. Factory automation was conceptualized and implemented with the initial start of the use of programmable controllers in the industry as mentioned in [2]. With the increasing ease of programming devices, automation processes could be sped up and made more complex. The changes in the software in factory automation have been highlighted by S. Ulewicz et. Al. in [9], which shows the various changes factory automation software has undergone for testing and application. We now proceed to enumerate some recent advances made in factory automation:

i. Empowerment of existing material handling systems: C. Hammel et. Al. in [10] introduce improvements to the Automated Material Handling Systems (AMHS) used presently in the industry. The improvements are made by selecting a suitable path for the delivery and also by trying to limit the number of vehicles trying to pass a given point at a time. Improvements are also made to the scheduling and dispatching of the products.

ii. Use of WLAN for factory automation systems:
With the advent of wireless technology, the use of wireless networks has become a viable and promising candidate for industrial automation applications. As highlighted in [11], the use of a WLAN for the control of various automated appliances in the factory can be used with acceptable performance with a decent level of processing speed and error rate.

iii. Factory Automation using adaptive frequency hopping communication: For further improving the performance of wireless systems for automation purposes, A. Wulf et. Al. in [12] presented a frequency hopping spread spectrum system with Gaussian Frequency Shift Keying for the transceiver technology. The results proved to be promising and it significantly improved the performance of the wireless system for factory automation.

III. POWER ELECTRONICS

A. Reliability

Over the past few decades, the use of power electronic systems has seen a tremendous increase in industrial applications. Numerous efforts have been made to make these systems more reliable and with higher life cycles, making them more cost effective. Reliability, which refers to the ability of a system to perform a required task under the given conditions for a certain period, of power electronics is measured in terms of three parameters – Analytical physics, Design for Reliability (DFR), and Verification & monitoring (see figure 1). As the complexity of the systems increases, their reliability in high power-density and high-temperature applications becomes critical. The challenges faced by designers of Power Electronic Systems have been elaborated in [13], along with the major areas where this reliability can be improved with increased cost effectiveness.

Another significant development in this field is the use of DC-based power sources as an alternative solution to the traditional AC network. This allows for easy and effective integration of Renewable Energy Sources (RESs) and electronic based loads into power systems. Recent findings have revealed that innovations in power electronics can lead to the development of efficient medium and low-voltage DC power (MV/LV DC), especially for smart grids with high penetration of distributed energy sources (DER) and electronic based loads.

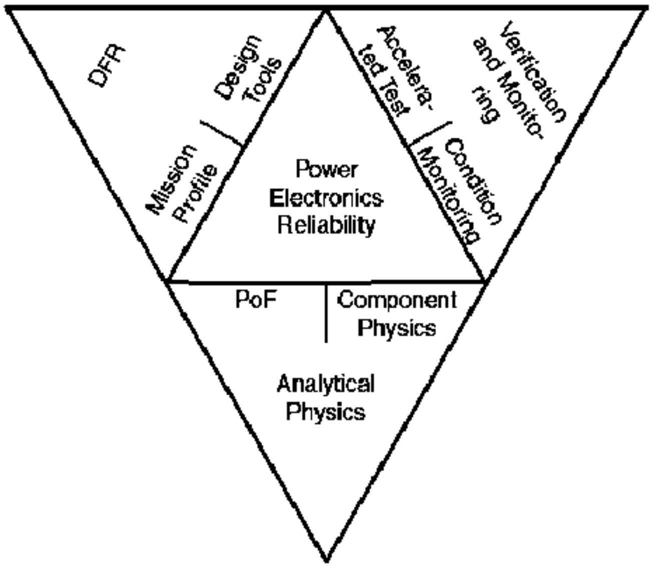

Figure 1 : Scope in power electronics reliability.

In terms of hardware topologies, it has been shown in [14] that DC-powered systems can be developed in the future

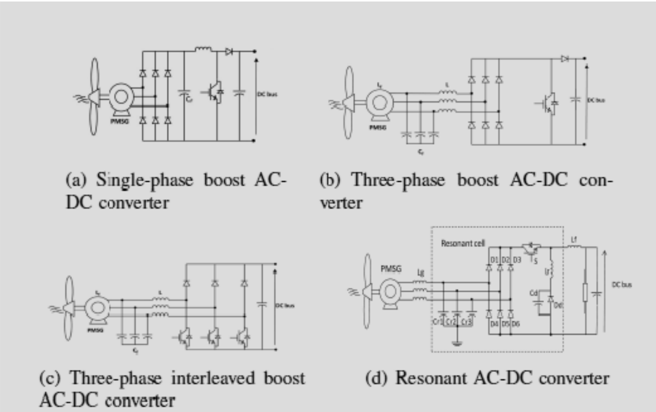

Figure 2:Different topologies of AC-DC unidirectional Converters.

by employing high-efficient power converter interfaces. Using an appropriate converter topology with suitable switching approach would increase the overall energy conversion efficiency up to 96% at Points of Common Coupling (PCC). A few such topologies,discussed in [14] are shown in figure 2, 3, 4, and 5.

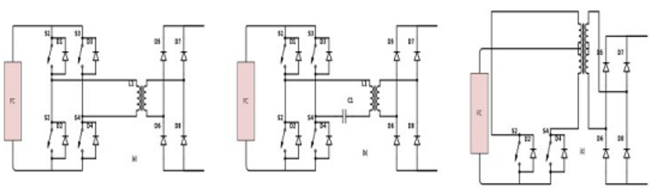

Figure 3:Isolated DC-DC converters: (a)full-bridge, (b) series-resonant, and (c)push-pull

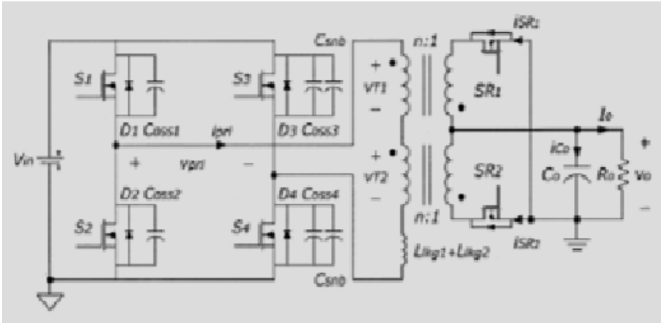

Figure 4: Full-bridge DC-DC converter with PSMT and zero voltage switching

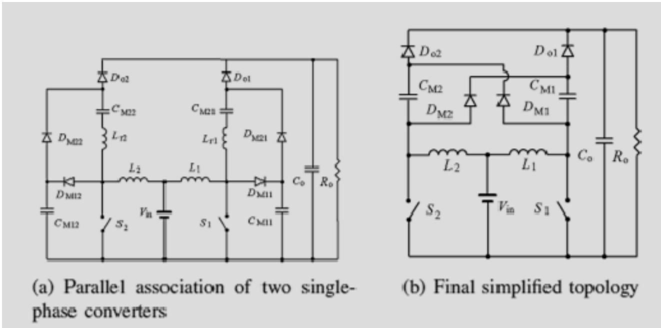

Figure 5: Voltage multiplier cell integrated with the two phase boost DC-DC

B. Model Predictive Control (MPC) in Power Electronics

MPC, being one of the most important advances in process control, finds significant applications in Power Electronics, especially in the different kinds of power converters, -like the DC-DC, DC-AC, AC-DC and AC-AC kinds. [15] The MPC algorithm, as applied in industrial electronics, has been shown in [15].

Other interesting applications of MPC are in the Battery Energy Storage Systems (BESS), Direct torque control, Torque Ripple Compensation, Static-Synchronous Compensator (STATCOM), as discussed in [16]. These applications are seen primarily at a research level. At an industrial level, however, certain other applications have been reported, given in table 2.

Application	**Sampling Rate in Hz**	**Company**
Integrated room automation	0.002	Siemens
Adaptive cruise control	2	Chrysler
Differential gearbox with backslash	25	-
Autonomous vehicle Steering	30	Ford
Traction control	50	Ford
Electronic Throttle Control	200	Ford
Voltage Source Inverters	10×10^3	-
Direct Torque Control	40×10^3	ABB
DC- DC Converters	50×10^3	STM

Table 2: Summary of MPC applications as reported by industry

C. Power electronics in Renewable Energy Sources.

The world is moving towards sustainable development. The installation of Renewable Energy Sources (RES) has been an important indicator of this progress in recent years. The output of these sources is, however, intermittent. Utility-scale battery energy storage systems (BESS), with their fast response characteristics can provide an economic and promising alternative to smooth the output power of RES [17]. BESS can provide multiple market related and grid support services. Power Electronics(PE) bridges the gap between BESS rated at tens of MWs and the Medium Voltage (MV) electricity grid [17]. The PE unit acts as an interface between the batteries and the electricity grid, controls the power flow of BESS, and regulates the operating points of batteries, thus elongating the life span of the BESS. Commercially viable PE topologies suitable for utility-scale BESS applications have been reviewed in [17] and their efficiencies have been thoroughly discussed and compared.

IV. CONTROL AND COMMUNICATION SYSTEMS

A. Multi Agent SCADA Systems

Supervisory Control and Data Acquisition systems have taken over the industrial world. They find applications in all modern industries and power transmission networks. They have modernized and made processes more efficient, and more optimized. SCADA systems are almost always based on one central server. However, recent developments as reported by Kosakaya [18] describe a Multi Agent based SCADA Systems, which improves the serviceability and leads to a maintenance free system. In the work done, SCADA systems have been implemented by Intelligent Field Terminals, which use a common algorithm agnostic to system specifications. The entire setup was analysed as a possible control mechanism to control the levels of various reservoirs of water within a certain range.

An Inter Terminal Parameter is used to ensure smooth communication among all the distributed agents, and to solve problems among negotiations, and to keep other agents immune to problems faced by one agent. The described system uses an adaptive Solitary/Cooperative Control Algorithm, which prioritizes the malfunctions as three events, as shown.

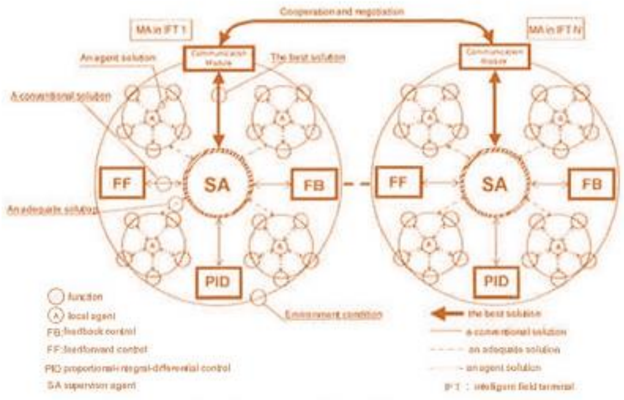

Figure 6: Architecture of Multi Agent SCADA System

Priority	Event	Event Definition
1	$\Delta H, \Delta P, \Delta V < K$	Normal
2	$\Delta H, \Delta P, \Delta V > K$	Minor Problem
3	$\Delta H, \Delta P, \Delta V >> K$	Critical Problem

Table 3: Error Event Priority

Based on the malfunction events the appropriate control variables X and Y are set values, and the required algorithm is executed as shown in the flowchart below.

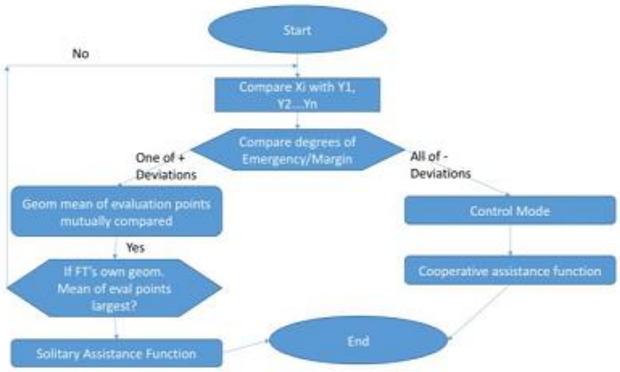

Figure 7: Error Correction Algorithm

This scheme of Multi Agent SCADA vastly improves the device specification independency, serviceability, and ensures a maintenance free operation. It takes care of inconsistencies in data processing by various terminals, via negotiation protools. Practical results also show that the convergence also reduces, which proves to be an added advantage over conventional SCADA. The future prospects of this are applications in Traffic Signalling, and Power Transmission Networks.

B. Neural Networks, Fuzzy Systems

The use of Neural Networks and Fuzzy Systems has seen prominence in recent Industrial Control Systems. Automated Neural Networks use advanced algorithms like Levenberg-Marquardt today, which are feed forward algorithms that do not propagate an error backwards [19]. Other Neural Networks exist, such as the radial basis function, counter propagation, and learning vector quantization. A fast and effective training algorithm called Neuron-by-Neuron has been developed which can train any feed-forward network, with a much greater efficiency than EBP, and an accuracy similar to LM. Recent Neural Network applications minclude:

1. Motor Actuation: This has been widely studied by many researchers. Various network topologies like Adaline, Multilayer, perceptron-cascade, and B-spline neural networks. Motors of all kinds were actuated, achieving a good control stability and set point convergence, based on the type of neural network used.

2. Fault Detection and Prediction: Machado et al. [20] presented a topology where faults were detected and corrected by algorithms in field device function blocks.

This was applied to Factory Automation. Neural networks help us not only detect and correct faults, but also analyse their pattern and prevent future events by taking appropriate maintenance measures.

3. Manufacturing: ANNs have helped in solving Scheduling problems with production line jobs. [21] have produced an algorithm that speeded up a Hopfield NN, making it easier and faster to provide a scheduling solution with a near optimum result.

4. Power Distribution and Handling: Neural Networks have helped generate clean power sources, by eliminating ripples, noises, distortions and phase mismatches. They analyse the pattern of the incoming aberration, and implement measures to predict and prepare for the next error instant, therefore providing a pure power source. Power sources can also be analysed for their properties using Neural networks, as proposed by Chang et al. [22] wherein the authors analysed harmonic amplitudes of measured current ripples, and regulated the supply accordingly. Experimental results have shown quick convergence, and a strong stability factor. Recent advances have given rise to hybrid NeuroFuzzy systems which improve in traditional fuzzy systems, and bridge the gap between neural networks and fuzzy systems. They do not require training like neural networks do, and can be directly designed from the fuzzy rule table. They produce more smoother control results, and an improved accuracy. However, the systems themselves are more complex and harder to design. They have been implemented in various applications, and in all cases have shown a better stability and performance than neural networks or fuzzy logic controllers alone.

C. Embedded MPU based Test Benches

In VLSI Economy, a transistor on a chip is practically free. What makes modern devices so expensive, are the costs incurred in the Bond wires, and that in testing the prototypes and assembly line samples. Testing machines and algorithms are both expensive to buy/hire, and also cumbersome. To alleviate this problem, Akhtar et al. [23] have provided a cheap, state diagram based, cheap, modular testing alternative, which has been implemented on a EVALSPEAr320PLC Board by the authors. Module based architecture is shown below:

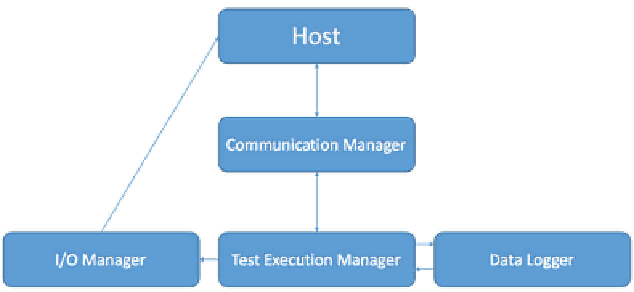

Figure 8: Architecture of [23]

The Test Execution Manager is designed as a State Machine. The host can send commands to the state machine on the target thru the AMC, or as contained in the Test vector definition. The state diagram is as shown:

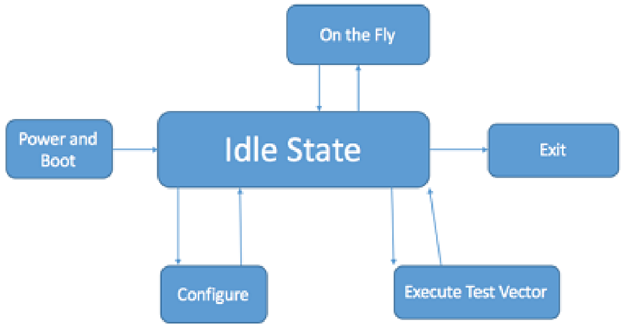

Figure 9: State Diagram of Tester

Data loggers are used to record all input and output data. There are two threads: Data logging and Data streaming threads, which read an add data to a Linked list.
Each linked node has a Data field and an address field, to store location of next node.
The work in paper [23] proves to be very cheap owing to the characteristics:

1. Reusability: This scheme being a reprogrammable development board, it can be used to perform any other function as well by uploading the appropriate code. Thus, the hardware is not limited to a single usage function. Multi-threaded programming enables an efficient sharing of resources based on use case requirement.

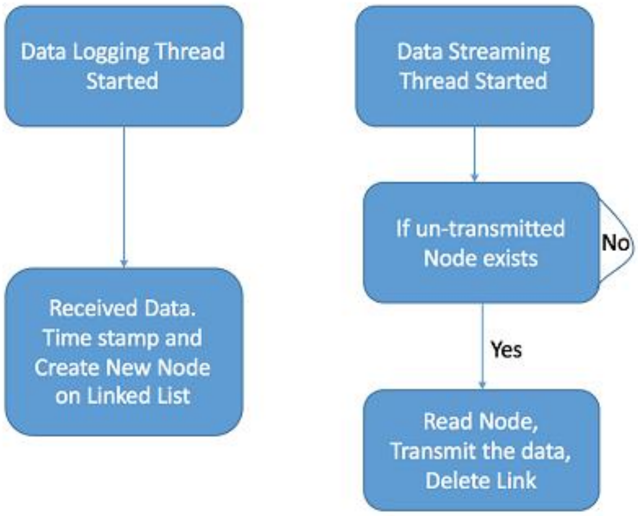

Figure 10: Data Logger Algorithm

2. The described scheme can be used for multiple communication protocols, some of which are Analog, GPIO, MODBUS, CAN BUS, and Ethernet. It can be used in an instantaneous input mode, or in a mode with the test input is defined as a vector.

3. The hardware (development board) used is very cheap. Compared to the competition in current use today.Any personal computer can be used to program the hardware,

making it agnostic to user PC specifications.

4. The software used in this scheme is an open source non-proprietary software, which means anyone can download and use it freely. The user is able to make changes to the program used, based on their requirement. There is complete freedom to program the hardware to suit the needs of the device to be tested.

V. CONCLUSIONS

The role of Electronics in the radical change and sophistication the various industries have gone through in the past few decades cannot be ignored. In this paper, we have highlighted some of the recent advances that have been made in the field of Industrial Electronics, some which have already been implemented in the industry and some which are still being researched upon. We have analysed the various subfields of Industrial Electronics namely- Robotics, Factory Automation, Power Electronics, Control Systems and Factory Communication Systems. While most of these subfields find applications in the manufacturing industries, fields such as Robotics and Control Systems are in use in the Service Industry as well, the 'ReceptionBot' and 'CareBot' mentioned in [7] being two very good examples. The use of BESS as a Renewable Energy Source, as discussed in [17] , highlights the importance of Power Electronic Systems with efficient, stable outputs, for successful utilisation of Renewable Energy and overall Sustainable Development. Verification has been made very simple by the work in [23], which also proves to be a much cheaper alternative.

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