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Automation in Fabrication Technique of Printed Circuit Boards [PCB]

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Abstract

Automation is a technique of automatically controlled operation of an apparatus, process or system by mechanical or electronic devices that takes place of human organs of observation, efforts and decision. To complete the transition, support its new equipment and prepare for new market demands and opportunities, the company needed to re-engineer its process infrastructure to support the additional challenges of Just in time delivery, integrated client support services and competitive price pressures. Central Electronic Fabrication Section is the nodal agency responsible for the fabrication of various electronics packages. Various agencies like Design groups, System Reliability Group, Project, Components Group, PCB Fabrication Facility and Online Quality check etc. interact with this facility for the realization of the electronic hardware. This paper presents the automation in fabrication technique of printed circuit boards. The company's goal is to manufacture 12 satellites per year, but they are currently manufacturing 4 to 6 satellites per year. Main reason for this less is unable to manufacture enough printed circuit boards. Hence it is proposed to implement the automated workflow system in Central Electronic Fabrication Section to expedite various activities, optimize the effort by means of HMI, less human intervention and reduce the paperwork. An automated workflow system is a computer system that is used to manage a series of tasks within an organization/process to produce a final outcome. At each stage in the flow, one individual or a group is responsible for a specific task. Workflow software ensures that the individuals responsible for the next task are notified and receive the data to execute their stage of the process.

Keywords: Reengineering; Integrated client support; Just in time; HMI; Workflow automation

Introduction

Automation technology is a crossover discipline that uses knowledge and scientific methods from numerous other technical sciences. An automatic machine is an artificial system that makes decisions based on the linking of inputs with the respective states of the system; these decisions then produce very specific desired outputs. Automated manufacturing systems [1] operate in the factory on the physical product. They perform operations such as processing, assembly, inspection, or material handling, in some cases accomplishing more than one of these operations in the same system. They are called automated because they perform their operations with a reduced level of human participation compared with the corresponding manual process. In some highly automated systems, there is virtually no human participation. Examples of automated manufacturing systems include:

- i. Automated machine tools that process parts
- ii. Transfer lines that perform a series of machining operations
- iii. Automated assembly systems
- iv. Manufacturing systems that use industrial robots to perform processing and assernbly operations
- v. Automatic material handling and storage systems to integrate manufacturing operations
- vi. Automatic inspection systems for quality control.

A automated workflow system is a computer system that is used to manage a series of tasks within an organization/process to produce a final outcome. At each stage in the flow, one individual or a group is responsible for a specific task. The objective of the Workflow software is to ensure that the individuals responsible for the next task are notified and receive the data to execute their stage of the process. The Central Electronic Fabrication Facility is the nodal agency for all the electronic Fabrication activities in ISAC. There are various agencies viz. Subsystem, T&E, PCF, Components group, Project, QC etc. which are interacting with CEFS during the process of realization of the electronic hardware. During each stage of fabrication, one of the above agency is responsible for the completion of the activity. By notifying the next responsible agency in advance, unnecessary delays can be avoided.

Problem definition

The existing system is able to manufacture less number of printed circuit boards [PCB] than the actual requirement of the company. The whole fabrication process of printed circuit boards from initial stage till the end stage has been carried out manually by the workers [2-4]. The flow of the printed circuit boards inside the fabrication department is uneven and the proper work distribution is not done. Hence the fabrication process is more time consuming and productivity is less. After each stage of fabrication process the manual inspection has been carried out and it is the main bottle neck problem of the existing system as its more time consuming and less accuracy because of the human interventions.

Need for automation

- 1. To increase the productivity.
- To reduce the breakdowns in the fabrication process and to have the continuous monitoring on the workflow for the higher management.

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3. To overcome the existing manual inspection by automated inspection system and to reduce the inspection time as in turn increases the accuracy.

Proposed solution

- An automated workflow management has been planned to control and monitor the whole fabrication process of printed circuit boards [5].
- 2. Reducing the paper work and to develop paperless workflow.
- 3. Developing an automated inspection method for the inspection of printed circuit boards.

Objectives of workflow automation

- 1. Developing Central Information and Management Software [CIMS] software [6].
- 2. Workflow process without breakdowns.
- 3. Achieving more productivity.
- 4. Fabrication activities by notifying to the next responsible agency after each stage in the workflow (including digital approval).
- 5. Automatic generation of reports and alarms/alerts.
- 6. Interactions with fabrication facility will be digital form helps to optimize manual effort and time and reduction in paperwork for all.
- 7. Current Fabrication status of all electronic hardware to all the interacting agencies at their desktops.

Objectives of automated inspection

- 1. Avoid bottle neck inspection in the fabrication process of printed circuit boards.
- 2. Making automated visual inspection.
- 3. Reducing the inspection time of printed circuit boards and increasing the accuracy of error detection.

Literature Survey

The research person Hopp in their paper have explored the causes of excessive lead time and suggest practical, inexpensive strategies for reducing lead time. Their suggestions are based on a detailed study of six manufacturing companies and a survey of literature in the related area. Hopp et al. have listed several techniques (based on queueing principles) for compressing manufacturing lead times. Some of the techniques for lead-time reduction discussed by them, such as inspection time reduction, have been explored in our work in the current paper.

The research person Suri presented Quick response manufacturing (QRM) is an important collection of techniques to compress process lead times in manufacturing firms. QRM principles include intelligent scheduling of bottleneck resources, product-oriented cellular organization, use of a judicious mix of push and pull control policies etc. It is argued that substantial improvement in lead time, of the order of 75%, in new product introduction, and 90% to fill orders for existing products can be achieved by using QRM techniques.

The research person Millson presents a survey for accelerating the new product development. The techniques for reducing the cycle time is (a) Simplify the process; (b) eliminate the delays; (c) eliminate steps; (d) speed up operations; and (e) make processes parallel.

The research person Lyons, in their report, have explained key requirements, industry practices, and research questions for new methods and computer tools for process modeling of the product realization. For production of large volume of circuit boards, the costs become less and the soldering can be done by fully automated machines. For PCB fabrication, some basic steps have to be followed.

Scope of the Project

By automating the PCB fabrication process the following scopes of the project has been defined as follows [7,8]:

- 1. Expediting fabrication activities by notifying to the next responsible agency after each stage in the workflow (including digital approval).
- 2. Automatic generation of reports and alarms/alerts.
- 3. Interactions with fabrication facility will be digital form helps to optimize manual effort and time and reduction in paperwork for all.
- 4. Current Fabrication status of all electronic hardware to all the interacting agencies at their desktops.
- 5. By designing and developing a new defect detection and localization algorithm for automated visual PCB inspection, can be applied to facilitate the reliability test of the product. The algorithm is designed for the inspection of both bare PCB panels and components mounted PCB panels.
- 6. This project emphasis on the development of an efficient and fast algorithm implemented of PC. Even though higher speed could be achieved using dedicated hardware or using DSP processor chips, it is beyond the scope of this project to evaluate or design the actual hardware system.

Methodology

Printed circuit board or in short PCB fabrication process is a multidisciplinary process. The each satellite will have the communication, control, display and miscellaneous systems which in total consist of 200 to 300 printed circuit boards piled up in stack of 5 to 10 printed circuit boards as per the required design [9]. The whole fabrication process has been done in the Central Electronic Fabrication System [CEFS] which is controlled by the Systems Engineering Group. In the existing system the fabrication process has been done manually using the human power in the ISRO Satellite Centre. The company didn't found any suitable clients to outsource the printed circuit fabrication process and they looking for the suitable loyal customers for outsourcing the printed circuit boards manufacturing. And the whole fabrication division located in the 2nd floor the ISAC main building.

Fabrication process

– Approved Fabrication Requests for PCBs and Packages from Subsystem.

- Fabrication details from Subsystem.
- PCBs from PCB fabrication lab.
- Components from Project.
- Receiving approved fabrication requests for PCB/Packages.
- Generation of pre-fabrication data based on the request.

- Sorting and issue components.
- Generation of list of components which are Not Available (NA List).
- Performing PCB Operations.
- Performing Package Operations.
- Performing rework if RDC (Rework Data Card) is given.
- Providing fabrication status of various cards and packages.
- Finished PCB/Package.

All the process and the test data, results has been noted down manually. Each printed circuit boards has been attached with the many color cards consisting of the invoices, process details, worker details and designation who carry out the fabrication process and the inspection. The results also have been manually written in the cards with the signatures of the operators, supervisors and as well as the approving authority [10]. After the fabrication of set of printed circuit boards the full information about the boards and the manually entered cards has been sent to the group head and the Division head. But this used to consume more time and the paper work was more. If in case any worker was on leave then the workflow will breakdown till the next immediate senior take over the responsibility to carry out that work or to supervise on behalf of actual person.

Workflow analysis

Before the actual fabrication there will be clearance from the Project Planning and Interfacing Committee [PPIC] and the full details of the process and operations to be carried out has been given to the fabrication committee. But all the details needed for the process and drawings, data has been manually collected and entered in the color cards. These cards have been filed and attached to the printed circuit boards during the whole fabrication process. After each and every process the workers manually enter the operations performed on the boards and the results on the cards. At the end of the process these files has been sent to the director for the approval and to mount on to the satellites. They actually manufacture two types of the models of printed circuit boards. They are Qualification model and Flight model. The qualification model in the initial test model processed to understand the design and behavior in the outer space atmospheric characteristics. The actual flight model will be used on the satellite which will be launched to perform the desired operations [11]. The inspection has been carried out by the visual inspection method. After fabrication process, quality check, inspection and packing of the boards then they have been delivered to Avionics Installation and Testing department for housing the printed circuit boards and to use them whenever necessary.

Inspection

In the existing printed circuit board fabrication process after each and every stage, the inspection has been carried out manually by the moderately skilled workers using visible inspection method. At various stages of the fabrication process, inspection is done. If the panel is accepted at that stage, it is passed on to the next stage. Otherwise, the panel goes back to rework, to the same stage of operation. But in some of the cases, the panel is rejected. For such cases, the panel inspection is critically important. If the panel is rejected after most of the fabrication process than it's a scrap which incurs huge loss for the company. A permanent rejection or scrap of a panel is not just a loss in terms of money as well as the process may stop for some time till the new panel arrives with acceptance. The Figure 1 shows how the inspection method has been carried out in the existing system.

Current practice in PCB fabrication requires etching process. This process is an irreversible process. The printing process, which is done before etching process, caused most destructive defects found on the PCB [12]. Any misprint will cause the etched board to be useless. Since laminated board constitute most of the total production cost, it is important that the board is properly inspected before being etched. Otherwise, the wrongly etched board will be thrown away. This, in return, requires a system to detect online or in real-time any defect caused by the printing process. The overall PCB inspection approaches, methods and techniques can be classified as depicted in Figure 2. Visual inspection is one of highest cost in printed circuit boards (PCB) manufacturing. Although many algorithms are available in defect detection, both contact and noncontact methods, none is able to classify these defects. Contact method tests the connectivity of circuits but unable to detect major flaws in cosmetic defects. Noncontact uses methods such as ultrasonic and x-ray imaging to detect anomalies in the circuit design, both cosmetic and functional. In image comparison techniques field, Hamada and Nakahata took inspected patterns to compare with design patterns to achieve a highly reliable inspection in 1990. They proposed two-step image processing inspection. The first step is the coarse alignment between the detected patterns and the design patterns. The second step is the defect detection named "Local Pattern Comparison" method in which small defects up to 1.5 pixelsize can be detected without being influenced by pattern registration errors and sampling errors. Ito and Nikaido proposed a topological comparison method, which compares the inspection graph obtained from the skeletons of the conductor and insulator images of an inspection PCB with those of the standard or reference boards. But actually ISRO management follows manual inspection method. They believed that their man power is enough for the better results. It is actually time consuming as the highly skilled workers are less in number.

There are 75 types of checklist which has to be manually entered by the workers after each process. This will be the reference for the next set of process to be carried out. The each check list will contain the details of the printed circuit board unique identification number for the easy identification purpose. In the each check list the different parameters has been tabulated and the outcomes of performing that action on that board in written. This obviously consumes more time and the human intervention will be more. The paper used for noting all these details will be more and the higher authority will not be able to go throw properly. The example of the visual inspection checklist is as shown in Figure 3. The other entire 76 checklist will be of similar type consisting of numerous parameters and the outcomes of the tests as per the sample checklist shown in Figure 3. Supervisor will also give the remarks for the correction of the errors.

Automation

The need for automation in the organization because the documentation work is more, checklist entering is more iterative, more breakdowns, improper workflow in process and the quality check or inspection is more time consuming achieving less accuracy. By analyzing the workflow in the fabrication department and the activity diagram I can clearly make sure the problems that are affecting the company's productivity and goals are,

- 1. Improper workflow with more breakdowns.
- 2. Manual inspection method because more time consuming and less accuracy.

I have carried out the brain storming sessions with the various department heads, group directors and senior workers to get the solutions for the above noted problems. Company also listed out some

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constraints such as they don't want to install any new machines and robots. Considering all the above constraints I was able to clearly come out with the solutions for above problems. The solutions are,

- 1. Automated Workflow System.
- 2. Automated Inspection System.

An automated workflow system is a computer system that is used to manage a series of tasks within an organization/process to produce a final outcome. At each stage in the flow, one individual or a group is responsible for a specific task. Workflow software ensures that the individuals responsible for the next task are notified and receive the data to execute their stage of the process. The Central Electronic Fabrication Facility is the nodal agency for all the electronic Fabrication activities in ISAC [13]. There are various agencies viz. Subsystem, T&E, PCF, Components group, Project, QC etc. which are interacting with CEFS during the process of realization of the electronic hardware. During each stage of fabrication, one of the above agencies is responsible for the completion of the activity. By notifying the next responsible agency in advance, unnecessary delays can be avoided.

Technical overview of automated workflow system

This application is a web-based, transactional, multi-tier application. It has been developed using the Tomcat Application Server and the My SQL Database which are both open-source projects and can be deployed with no licensing cost. The application was developed using advanced technologies including Java, JavaScript, and, HTML. Currently it is planned to be deployed Windows Operating system. Application diagram helps client can get an äctual feel"of the system, since the application diagram enable the client to better understand the requirments of the desired system. Here the user interface has been built using the Java Server Page[JSP], Application logic has been built and coded using java programming, data access has been connected to the data base using Java Data Base Connector[JDBC] and all the data has been stored in the MySQL database [14]. The user will be interacted using the Hyper transfer Protocol[HTTP] and when the user open the web page all the details as been retrived by the MySQL and displayed on the web page.

Automated inspection system

The newly proposed inspection system capture the images using the CCD camera and that image will be processed to get the output which gives the clear picture about the defects in printed circuit boards. Figure 4 shows how the proposed inspection method works. Figure 5 shows the actual automated inspection system installed in the ISAC organization. Therefore, inspection of the boards before shipment to customers is required. Many customers specify PCB inspection requirements so they can be assured of receiving quality, working product. However, as PCBs become smaller, more complex, and manufactured faster, inspection has become more difficult to successfully accomplish. Magnifiers and Microscopes have been used for inspection but this methodology often cannot meet the speed and/or resolution requirements to accurately inspect high volume PCBs. Therefore, suppliers are moving quickly to a more sophisticated approach using camera to automate the various inspections required.



Figure 4: Application Diagram of the proposed automated workflow system.



Figure 5: Automated Inspection System.



Inspection flow chart

The machine-vision software is the centerpiece of the inspection system. The software selected will determine the length of time required to generate and debug inspection programs, what inspection operations can be performed, how well those operations can be performed, as well as many other important factors. Machine-vision software packages that provide a graphical user interface are usually easier to program than their code (Visual BASIC or Visual C++) counterparts but can sometimes be limited when specialized features or functions are required. Although they require programming expertise, code-based packages can be more flexible if you're developing complex application-specific inspection algorithms. Some machine-vision software packages offer both graphical and codelevel development environments, providing the best of both worlds and giving users the additional flexibility of selecting the environment needed to match the application requirements as well as the programming expertise available.

Results and Conclusion

- 1. We managed to complete the project with a great success in testing and coding for the automated workflow software for the PCB fabrication process. By this the higher authority was able to receive all the information about the fabrication activities whenever they want.
- The software was able to re-route the printed circuit boards properly to the different departments analyzing the workloads of the departments.
- 3. The workflow software was able to alert the next responsible agency after each stage in the workflow to carry out the next set of fabrication activities.
- 4. The software was able to achieve the paperless automation by creating the standard digital forms for each and every activity. This reduces the manual entry of checklist throughout the full fabrication process.
- 4. Interactions with fabrication facility will be digital form helps to optimize manual effort and time and reduction in paperwork for all. Current Fabrication status of all electronic hardware to all the interacting agencies at their desktops.
- 5. We managed to complete the project with a great success in testing and coding for the defect detection on the bare PCB. Indeed, throughout this project, we have learnt how to use the OpenCV library in Visual Studio C++ 2010. We were also exposed to the effects of different kind of lighting condition which could affect the performance of the algorithm. This project enables us to apply the knowledge and theory that has been gathered during project analysis stage to solve real life problems.
- 6. The hardware implementations has provided a better perspective as the implementation was confined to dedicated system architecture and could be implemented on CEFS with much better results the software part depends on the Operating system and processor speed which provide many constraints.
- 7. Because of time constraints the present implementation has been confined to the part after the image has been acquired for a perfect implementation of this system, there is a need to embed a camera for image acquisition and dynamic implementation of this system.

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