ELECTRON BEAM STERILIZATION

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Laporan projek ini dikemukakan sebagai memenuhi
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ABSTRACT

Nowadays, an automation technology confront with a difficulty in constructing equipments for applications in the highvoltage side. Programmable logic controllers (PLC) and other electronic components for example have to be protected against over-voltages and in the case of electron beam systems also against x-rays. This is expensive and not easy to achieve but possible. The project is consists of three stages. The first stage demonstrates, through experimental on two parts of circuit boards inside the highvoltage deck of electron beam accelerator unit; filament control circuit board and beam control circuit boards. In these circuit boards, an analog signal flow from low voltage sides via optical link cable to the ground and transmitted to the highvoltage side. The calibrations are made to ensure it's operated correctly. The second stage is to generate a new method of filament control and beam control circuit by constructing a Programmable Logic Controller (PLC) using the STEP 7- Micro/WIN32 and SIMATIC WinCC software provided by SIEMENS AG. It is capable to operate under a highvoltage potential. It uses a PROFIBUS technology as the central connecting link for digital signal flow in the system. The advantages of digital solution are the speed of data transmitting in both directions are faster and better signal to noise ratio (SNR) than analog solution. Finally, as the circuits in both projects are operated under a highvoltage potential, thus there will be a conflict with the transient voltage upon the components, equipments and cables installed in the circuits. Therefore, in the third stage, one circuit protection is created and examined to show transient voltage fault investigation methods and possible solutions. At the end, this project is attempted to expand the automation technology in highvoltage area and support future development in this area

ABSTRAK

Kini, teknologi automatif menghadapi kesukaran dalam mengendalikan pelbagai peralatan di kawasan bervoltan tinggi. "Programmable Logic Controller (PLC)" dan peralatan elektonik yang lain sebagai contohnya hendaklah di dilindungi daripada voltan lampau terutamanya untuk sistem sinaran elektron juga sinar-x. Pembangunan projek ini terbahagi kepada tiga peringkat. Peringkat awal projek melibatkan pengujian ke atas dua buah papan litar yang akan dipasang di dalam "dek voltan tinggi", unit pemecut sinaran elektron; litar kawalan filamen dan litar kawalan sinaran. Isyarat analog digunakan sebagai agen penghantaran melalui kabel perhubungan optik dari bahagian bervoltan rendah ke bumi sebelum di hantar ke bahagia n bervoltan tinggi. Penentuukuran di laksanakan untuk memastikan kedua-dua litar beroperasi dengan tepat. Peringkat kedua melibatkan penghasilan fungsi litar yang sama seperti peringkat pertama tetapi dilaksanakan melalui kaedah yang baru iaitu dengan mengadaptasi PLC menggunakan perisian STEP 7 Micro/WIN32 dan SIMATIC WinCC daripada SIEMENS AG. Ia menggunakan teknologi PROFIBUS sebagai pusat rangkaian perhubungan untuk isyarat digital dihantar di dalam sistem. Kelebihan isyarat digital ialah kelajuan penghantaran data di kedua-dua arah dan isyarat-ke-hingar (SNR) lebih baik daripada isyarat analog. Di sebabkan litar di kedua-dua projek terletak di bahagian bervoltan tinggi, maka akan wujud permasaalah terhadap voltan lampau ke atas komponen, peralatan dan kabel yang dipasang di dalam litar.Oleh itu di peringkat ketiga projek, sebuah litar perlindungan dicipta dan diselidik untuk mengetahui pertahanan terhadap voltan lampau dan penyelesaiannya. Akhirnya, projek ini berupaya memperkembangkan penggunaan teknologi automatif ke bahagian bervoltan tinggi dan menggalakkan penggunaannya di masa akan datang..

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AC	-	Alternating current
AI	-	Analog Input
AO	-	Analog output
CPU	-	Central Processing Unit
SPD	-	Surge Protective Device
ADC	-	Analog-to-Digital converter
DAC	-	Digital-to-Analog converter
DB	-	Data Block
DC	-	Direct Current
DI	-	Digital Input
DO	-	Digital Output
FB	-	Function Block
FBD	-	Function Block Diagram
FC	-	Function
TD	-	Time Delay
MPI	-	Multipoint interface
OB	-	Organization block
PLC	-	Programmable logic controller
PG	-	Programming device
PS	-	Power supply
STL	-	Statement List
UR	-	Universal rack
FO	-	Fiber Optic
DP	-	Distributed Peripheral
OBT	-	Optical Bus Terminal

IM	-	Interface module
LAD	-	Ladder logic diagram
OB	-	Organization block
OS	-	Operator system
EOG	-	Ethylene Oxide gas
DNA	-	Deoxyribonucleic acid
LED	-	Light-emitting Diode
IC	-	Integrated Circuit
mG	-	milligauss
V/m	-	Volt per meter
nF	-	nano Farad
V	-	Voltage
kV	-	kiloVolt
I	-	Current
A	-	Ampere
kA	-	kiloAmpere
mA	-	miliAmpere
EXFS	-	The Extended Foil Polystyrene Capacitor
F/V	-	Frequency-to-Voltage
V/F	-	Voltage-to-Frequency
PCB	-	Printed Circuit Board
TVS	-	Transient Voltage Suppressor
RMS	-	Root Mean Square
A	-	Gain
keV	-	kilo Electron Volt
μm	-	micrometer
kGy	-	kiloGray
MTBF	-	Mean Time between Failures
MTTR	-	Mean Time to Repair
SNR	-	Signal-to-Noise ratio
PROFIBUS	-	Process Field Bus

MBP	-	Manchester Coded, Bus Power
DP	-	Decentralized Periphery
FMS	-	Fieldbus Message Specification
I/O	-	Input Output
RAM	-	Random Access Memory
MB	-	Megabyte
IDL100	-	Intelligent Data Logger
IM	-	Interface Module
OBT	-	Optical Bus Terminal
FO	-	Fiber Optic
CH	-	Channel
WinCC	-	Window Control Centre
Vin	-	Input Voltage
Fout	-	Output Frequency
UVL	-	Under Voltage Limit
TTL	-	Transistor-Transistor Logic
GSD	-	Electronic Data Sheet or Geraestammdatei (German abbreviation)
TMPTA	-	trimethylolpropane triacrylate
PTFE	-	polytetrafluoroethylene

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CHAPTER I

INTRODUCTION

This chapter is described about the project's introduction. It consists of objectives, scopes of the project, methodology and literature review.

1.1 Project Aim

The project aims are to compare the performance between the conventional circuits of filament control and beam control circuit boards with a new application of electron beam regulation using a standard components and worked correctly under a high voltage potential.

1.2 Objective

The primary objectives of this thesis are threefold. The first objective is to analyze the operation of a new filament control and beam control circuit boards inside the High Voltage Deck of electron beam sterilization unit whether it's running with the correct operation. In this conventional method, data is transmitted or received in analog signal between low voltages to high voltage side. The second objective is to generate a new method of filament control and beam control circuit by constructing a Programmable Logic Controller (PLC) that capable to operate in a high voltage side using standard equipments such as ET200M, PROFIBUS cables, Analog Digital Converter (ADC) or Digital Analog Converter (DAC) and others. The most important thing, it uses a PROFIBUS technology as the central connecting link for signal flow in the system. Hence, this method is compared whether it working similar or had a better performance than the conventional method. The third objective is to determine the effects of electric and magnetic fields generated by surge voltage or transient voltage on electronic measuring circuits for both methods. Therefore finding out the means for protecting or decreasing the effects of such interferences by choosing the suitable surge protective devices installed into the circuits.

1.3 Scope Of The Project

Scope of the project will be converging into a circuit board assembly that consist of filament control and beam control circuit board. A test is implemented to ensure a correct circuit operation as it been upgraded with a modern electronic devices to have a better availability rather than the old circuit boards. Then, it is concentrated in constructing a simulation of electron beam regulation using PLC with PROFIBUS communication protocol, STEP 7 and SIMATIC WinCC software, ET200M with ADC/DAC and tested under high voltage potential without generated an error in data transmission. Finally, the project is focus on a protection of a dummy circuit created against surge voltage in a High Voltage Laboratory.

1.4 Research Methodology

Research is needed to define and evaluate suitable methodologies and technique in order to identify and specify the accuracy of the instrumentations performed by using exact procedure shows in Fig. 1.4. The procedures are divided into a three different stages to ensure the proper implementations are established. The project method firstly established by calibration of the filament control circuit board for two type of capacitor and compared the performance of the circuit board upon the variation of a temperature. There are several kinds of experiments that have been accomplished during these calibrations. It consists of an experimentation of a voltage-to-frequency conversion and frequency-to-voltage conversion as the frequency of the filament set will be in the range of 10 kHz to 100k Hz with DC voltage varying from 0V to 10V and vice versa. It is important as the circuit will be located under a high voltage potential and confront with temperature arising cause by spark, corona or x-radiation. The temperature sensor is attached to capacitor for collecting the temperature variation and directly wired to Data Logger for collection a data. Also, the voltage probe is installed at Pin 7 TL084P to record the voltage value as the temperature varied. Using the data logger software, ICP100 the data is downloaded to the computer and exported to a spreadsheet application such as Microsoft Excel for a data analysis.

In a second stage, the project implementations began by determined the automation task. The tasks are; to set the voltage regulation and current limiter for the GENESYS^{TM} power supply by adjusted the DC power supply remotely and; to simulate the electron beam regulation using a STEP 7 software and SIMATIC WinCC. The project is created with the SIMATIC Manager as the central window which becomes active when STEP 7 is started. The project structure is used to store and arrange all the data and programs in order. Thus, after created a project with SIMATIC station the hardware used for the project is configured such as PLC, Programming Device, Programming Software and Connector Cable are assemble on the rail. The hardware is configured with STEP 7. These configuration data are transferred to the programmable controller later on "downloading". After the hardware connection is finished, then a software STEP 7-

Program is required in order to inform the PLC what instructions it must follow. The program is created in a standard language Statement List (STL) rather than Ladder Logic or Function Block Diagram. Thus, before download the program, we have to make sure the entire components already establish an online connection to the central processing unit (CPU), the CPU is in RUN or RUN-P mode, and the program is downloading. In STEP 7, OB1 is processed cyclically by the CPU. The CPU reads line by line and executes the program commands. When the CPU returns to the first program line, it has completed exactly one cycle. The STEP 7 programs of this project are included organization block (OB), function block (FB) and data block (DB). In an extreme case, the CPU goes into STOP while processing an S7 program, or the switch of the CPU not in a RUN mode after downloaded the program. The cause of the error is determined from the events listed in the diagnostic buffer.

Finally in the third stage, for an overvoltage protection system; a dummy circuit that consist a combination of integrator and Schmidt Trigger is designed. The experiment is not implemented to the original circuit used in stage 1 and 2 because the possibility of damaging the circuit is high. The original circuits or equipment are complicated and the components used are expensive. Therefore, it is more convenient if using a circuit which are easy to recreate and cheaper than the original circuits. Furthermore, if this experiment is able to protect the dummy circuit, then it also possible to protect others circuits. An appropriate surge protective device is installed in Zone 1 and 3 as the circuit protection and the experimental is conducted inside a high voltage laboratory for spark over tested. If the experiment is failed in protecting the dummy circuit, the experiment is started again by replaced the surge protective device or reconstructed the protection circuit. If the experiment is successfully protected the dummy circuit, therefore the replacement of the dummy circuit with a circuits in stage 1 and 2 can be accomplish.

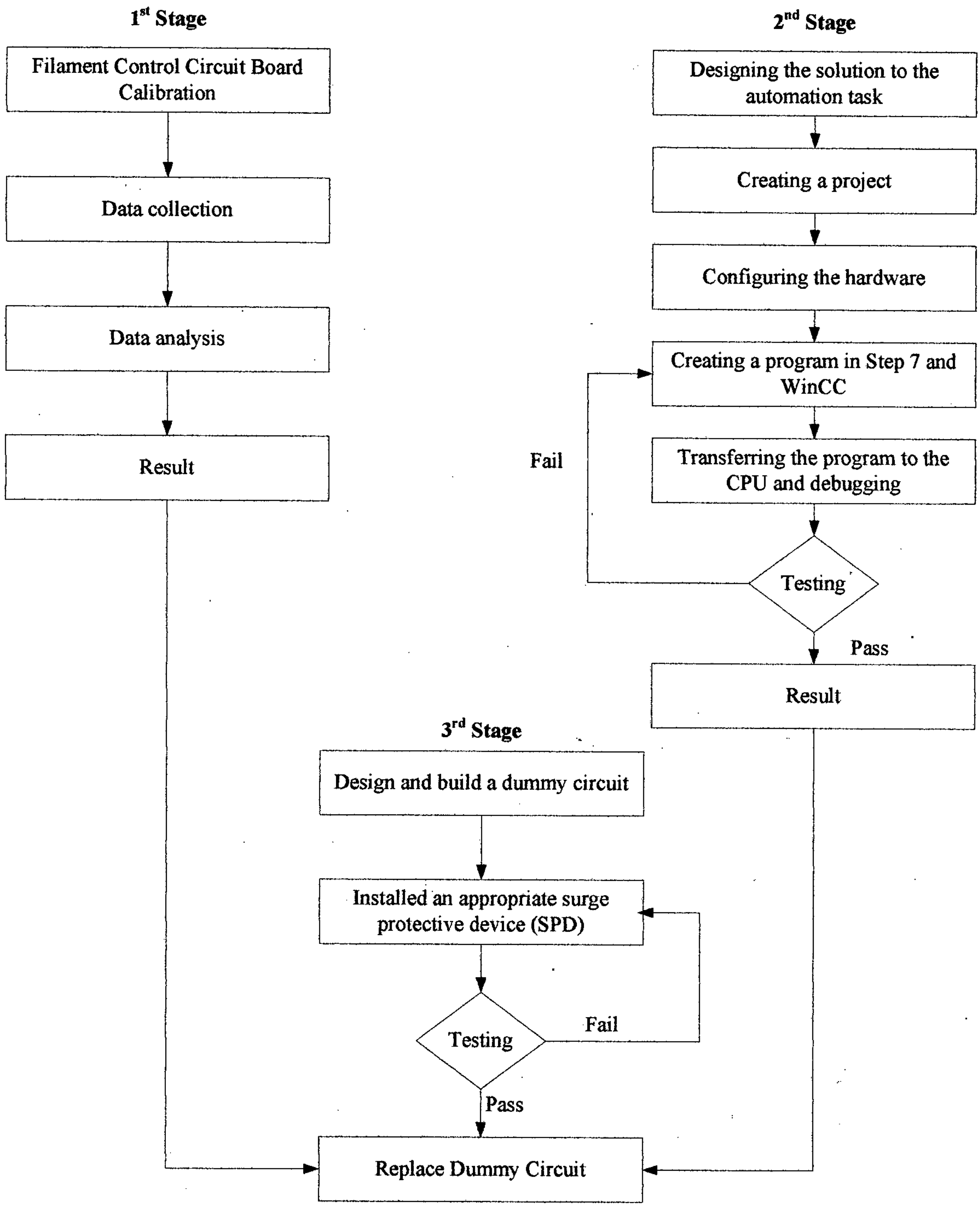

Figure 1.4: Flow chart of project research methodology

1.5 Literature Review

1.5.1 General Electron Beam

For over sixty years the physical and chemical changes induced by absorption of radiation sufficiently high in energy to produce ionization have been the subject of both university and industrial research. At this time, the most common commercial sources of ionizing radiation are ^{60}Co and ^{137}Cs for gamma irradiation and electron accelerators for e-beam (beta) irradiation (Singh and Silverman, 1992). When the electron-beam generated by an accelerator is directed at a target consisting of a high-atomic-number metal, such as tungsten, X-rays with a broad spectrum of energies can also be produced. Industrial irradiation processes using high-power electron accelerators are attractive because the throughput rates are very high and the treatment costs per unit of product are often competitive with more conventional chemical processes. The utilization of energy in electron beam processing is more efficient than typical thermal processing. The energy is delivered directly to the molecules, thus there is no need to heat the material in ovens or tools, or to allow for permeation of chemicals into the material being processed. The use of volatile or toxic chemicals can be avoided. Strict temperature or moisture controls may not be needed. Irradiated materials are useable immediately after processing. These capabilities are unique in that beneficial changes can be induced rapidly in solid materials and preformed products. The amount of electron beam radiation absorbed by the target is referred to as the dose, which is typically defined in terms of kiloGrays (where 1 kGy=1000 J/kg) or MegaRads (where 1 MRad=1,000,000 erg/g) (Bly, 1988). The number of electrons emitted per unit of time is dependant upon the power of the electron accelerator. This is expressed in kW. According to the treatment to be carried out, the power of the electron beam may vary from 10 to several hundreds of kW, for energy of 5 to 10 MeV.

1.5.2 Electron Beam Application

Crosslinking plastic materials, sterilizing medical products or packaging material and preserving foods were the earliest developments of electron beam processing. Processes for curing monomeric coatings and inks were developed somewhat later. The use of these and other processes has grown and they are widely practiced today. Electron beam crosslinking is used to produce heat-shrinkable plastic films for packaging foods and other consumer products, heat-shrinkable plastic tubing, heat-shrinkable plastic film and plastic pipe. The insulation on electrical wires and the jackets on multi-conductor cables are crosslinked to increase heat tolerance and to improve the resistance to abrasion and solvents. Crosslinked plastic pipe is used for hot water distribution systems. Radiation cured, solvent-free coatings and inks are used for magazines, newspapers and a variety of packaging materials.

All forms of ionizing radiation interact with matter by transferring energy to the electrons orbiting the atomic nuclei of target materials. These electrons may then be either released from the atoms, yielding positively charged ions and free electrons, or moved to a higher-energy atomic orbital, yielding and excited atom or molecule. These ions, electrons, and excited species are the precursors of any chemical changes observed in irradiated material (Cooper, Curry and O'Shea, 1998). Thus, by using ionizing radiation, it is possible to synthesize, modify, crosslink, and degrade polymers. Electron beam radiation is a distinct and efficient means of bringing about controlled beneficial changes in polymeric systems. These beneficial changes include increases in modulus, tensile and impact strength, hardness, deflection and service temperature, stress-crack resistance, abrasion resistance, creep and fatigue resistance, and barrier properties (Gehring and Zyball, 1995). In the polymerization for composites material, doses are usually in the range of 100 to 200 kGy (Berejka and Eberle, 2002, Kerluke and Cheng, 2002). Electron-beam processing offers significant improvements in processing technique, curing time and cost.

1.5.2.1 Sterilization

Likewise, ionizing radiation has the ability to break the chains of DNA in living organisms, such as bacteria, resulting in microbial death and rendering the space they inhabit sterile (Bly, 1988). During last years the electron beam treatment is more and more widely used for the sterilization of various medical devices and preparations. The electron beam sterilization of disposal syringes is now a norm. But not only syringes, but the single use devices for blood exchange, gynecologic endings, gloves, disposal cloths for operations, are now sterilized by electron beam (Auslender, 1994). The machines with electron energy of 10 MeV are usually used for these purposes. These machines are rather complicated and expensive. The Budker Institute for Nuclear Physics has designed and supplied irradiation facilities operating in many countries. One of the supplies is the automated installation for sterilization of single-use syringes working in the city of Izhevsk, Russia (Auslender, Polyakov and Golnik, 1993). The technology for sterilization of syringes permitted to use the electron beam with energy of 2.5-4 MeV. One of the main technological problems of electron beam sterilization of syringes is the achievement of maximum possible homogeneity of dose distribution. The high dose inhomogeneity leads to low quality of sterilization, as the lower dose limit 25 kGy is determined by the resistivity of microbes, and the greater dose leads to sufficient degradation of mechanical properties of plastic syringes.

1.5.2.2 Polymerization

(a) Coatings, Adhesives and Inks

Solvent-free coatings, adhesives and inks are cured (polymerized) by treatment with low-energy electron beams. These materials are combinations of oligomers (polymers with low molecular weights) and monomers, which control the viscosity before curing. Volatile solvents are not needed and curing occurs without loss of material. Typical oligomers are acrylated urethane polyesters, acrylated epoxies and polyethers. A typical multifunctional monomer is trimethylolpropane triacrylate (TMPTA). Dose requirements are relatively low, in the range of 10 to 30 kGy, and line speeds as high as 1500 m/min are achievable at 10 kGy with high-current, low-energy, multiple-beam electron accelerators (Nablo and Tripp, 1977).

(b) Composite Materials

Fibre-reinforced composite materials are used where greater strength is needed. Such materials are usually cured with heat, but electron-beam curing offers significant improvements in processing technique, curing time and cost. Typical materials are acrylated epoxies with carbon fibers. Doses are usually in the range of 100 to 200 kGy (Berejka and Eberle, 2002, Kerluke and Cheng, 2002). Initial formulations are mixtures of oligomers and monomers. The radiation curing process involves a combination of polymerization and crosslinking. The main applications are in automotive and aerospace industries.

1.5.2.2 Grafting

Grafting is polymerizes a monomer onto the polymer chain; modifies the surface properties of a polymer substrate; introduces new functionalities. The surface properties of polymers can be modified by graft copolymerization with different monomers (Chapiro, 1962). Grafting can be accomplished by electron beam irradiation on common polymers such as polyethylene, polypropylene and fluoropolymers. Most work has been done on polymer films, membranes, fibers and natural and synthetic textiles. Some examples of monomers that can be grafted onto polytetrafluoroethylene (PTFE) films are styrene, acrylic acid, 4-vinylpyridine and Nvinylpyrrolidone (Chapiro, 1977). Other applications include ion exchange membranes, fuel cell/battery separator films, permeation separation membranes, surface adhesion promotion, chelating fibers for seawater treatment and recovering of precious metals, etc. Some dose requirements may be less than 10 kGy.

1.5.2.4 Crosslinking

Crosslinking is the most important effect of polymer irradiation because it can usually improve the mechanical and thermal properties and chemical, environmental and radiation stabilities of preformed parts as well as bulk materials. It forms a network among the polymer chains and increases the molecular weight; improves temperature resistance, chemical resistance, and mechanical properties. Both polymer crosslinking and degradation by chain scission occur during treatment, but one or the other of these effects may be predominant in some materials (Silverman, 1981; Charlesby, 1977). Typical dose requirements for crosslinking are in the range of 50 to 150 kGy. Additives, typically multifunctional monomers, may be mixed with the basic polymer to enhance the crosslinking effect and reduce the dose requirement. Antioxidants, UV stabilizers and flame retardants may also be added to meet industrial performance specifications. Such additives may reduce the crosslinking effect. So, the properties of commercial compounds may be different from those of pure polymers.

(a) Insulated Wire and Cable

The crosslinking of insulation on electrical wires and cables was one of the first practical applications of electron beam processing. It was introduced by the Raychem Corporation during the 1950s, and it has been adopted by many other manufacturers since then. Some polymers used in this application are polyethylene, polyvinylchloride, ethylene-propylene rubber, polyvinylidene fluoride, and ethylene tetrafluoroethylene copolymer. Product improvements obtained by irradiation include increased tolerance to high temperature environments and overloaded conductors, fire retardation, increased abrasion resistance and tensile strength,