ELECTRON BEAM STERILIZATION

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ABSTRACT

The project consists of three stages. The first stage demonstrates, through experimental works on the highvoltage deck of electron beam accelerator unit; filament control circuit board and beam control circuit boards. In these circuit boards, an analog signal flows from low voltage sides via optical link cable to the ground and transmitted to the highvoltage side. The calibrations were made to ensure its safe operation. The second stage was 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 the 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 were operated under a highvoltage potential, there would 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 was created and examined to show transient voltage fault investigation methods and possible solutions. At the end, the project is attempted to expand the automation technology in highvoltage area and support future development in this area

ABSTRAK

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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LIST OF ABBREVIATIONS

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
V	-	Voltage
I	-	Current
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
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

LIST OF SYMBOLS

V	-	volt
A	-	ampere
mG	-	milligauss
V/m	-	Volt per meter
nF	-	nano Farad
V	-	Voltage
kV	-	kiloVolt
kA	-	kiloAmpere
mA	-	miliAmpere
keV	-	kilo Electron Volt
µm	-	micrometer
kGy	-	kiloGray
%	-	percent
^{o}C	-	degree celcius

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CHAPTER I

INTRODUCTION

This chapter describes about the project's introduction. It consists of overview, project aim, objectives and scopes of the project.

1.1 Overview

Nowadays, automation technology confront with a difficulty in constructing equipments for applications in the highvoltage aspects. 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. The project was implemented based on the electron beam sterilization system provided by a company in Sweden; Electron Crosslinking AB. Accomplishment of this project was focused on a new electronic design of two circuit boards inside the High Voltage Deck of the electron beam unit. In this system, the PLC used for controlling the data was located in low voltage side and the circuit boards were placed under a high voltage potential. It was required to transmit data from low voltage side to high voltage and back. Till now, there was no path for PLC which was designed to be used in the high voltage side thus the data has to be sent to the ground before it was transmitted to the high voltage side. The data was transmitted in analog signal. The functions of filament control and beam control circuit boards was similar with the original circuits but with a better availability. It is a new electronic design with a modern electronic devices installed onto it. The procedure of calibration in each circuit board must be fulfilled to ensure the circuit can work at the correct operation before it was being replaced.

As a comparison between both circuits, another project was designed with a similar operation but dissimilar in method. This project was able to operate the same as the filament control and beam control circuit board of electron beam sterilization system but with the different equipments, components, technique, and process development. The PLC used is able to control the filament current and grid voltage by assumption made in the real circuit boards. However, it significant for this project to operate with a high availability, low in cost and has better performance than the original circuit board. Consider of using a PROFIBUS technology as a protocol for communication in the system, the data was transmitted in digital signal which has the advantages than an analog signal transmission. In general, PROFIBUS is an open, digital communication system with a wide range of application and suitable for fast and complex communication tasks.

During the system design process, no matter how well a system was designed, or how reliable the components was the cost involved due to failures cannot be eliminated completely. However, it is possible to manage failures in order to minimize the impact on a system. Driven by productivity demands, the focus is more concentrated to equipment availability. The impact of availability is cause by machine downtimes analysis. The economic justification for a project is generally based on the lifetime cost of the project. A major contribution to this cost involves an evaluation of the availability of the equipment. Availability is typically expressed in percentage of time the system is available or in downtime per year. Availability is commonly defined through the following equation:

$$Availability, A = \frac{MTBF}{MTBF + MTTR} \quad (2.1)$$

where

MTBF = Mean Time between Failures
MTTR = Mean Time to Repair

MTBF, a measure of time elapsed between breakdowns that cause production stops. MTBF by definition is the total running hours divided by the number of failure. Hence, MTTR, a measure of how long it takes to get the equipment operational again after a production stop. It depends on how quickly the failure are detected and repaired. From the availability equation, there are several ways to increase a system's availability such as increasing the MTBF and reducing MTTR of the system.

1.2 Project Aim

The project aims were to compare the performance between the conventional circuits of filament control and beam control circuit boards with a new method of electron beam regulation using a standard components that can work correctly under a high voltage potential.

1.3 Objectives

The primary objectives of this project are threefold. The first objective was 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 is running with the correct operation. In this conventional method, data was transmitted or received in analog signal between low voltages to high voltage side. The second objective was to generate a new method of filament control and beam control circuit by constructing a

Programmable Logic Controller (PLC) that was able 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 used a PROFIBUS technology as the central connecting link for signal flow in the system. A comparison was made between the method and the conventional methods. The third objective was to determine the effects of electric and magnetic fields generated by surge voltage or transient voltage on electronic measuring circuits for both methods and hence finding a mean for protecting or decreasing the effects of such interferences by choosing the suitable surge protective devices installed into the circuits.

1.4 Scope Of The Project

The scope of the project includes a circuit boards assembly that consisted of filament control and beam control. A test was implemented to ensure a correct circuit operation as it was upgraded with a modern electronic devices to have a better availability rather than the old circuit boards. Emphasis was also concentrated in constructing a simulation of electron beam regulation using a PLC with PROFIBUS communication protocol, STEP 7 and SIMATIC WinCC software, ET200M with ADC/DAC and tested under a high voltage potential without generated an error in data transmission. Finally, the project focussed on a protection of a dummy circuit created against surge voltage inside a High Voltage Laboratory.

CHAPTER II

LITERATURE REVIEW

This chapter presents several important issues related to electron beam and its associated technologies.

2.1 General Electron Beam

For over sixty years the physical and chemical changes induced by absorption of radiation was 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.

2.2 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

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