Digital Controller Design for Microalternator Set

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Abstract

A digital controller for the microalternator set was implemented in the power laboratory, Universiti Teknologi Malaysia. Description of the hardware and software development is presented in this paper. This paper also presents test results of automatic voltage regulator using the PI and PID control of various loads.

I Introduction

The microalternator set is a three phase synchronous machine which possess the same electrical constants as those normally found in alternators in modern power stations[2,3,4]. It is an electrical scale model of machines of up to 1000MW rating and is rated at between 1 and 5 kVA, approximately one millionth of the rating of the simulated machine. The micro machine available in the Faculty of Electrical Engineering, Universiti Teknologi Malaysia is rated at 3 kVA, 220 Volt. The micromachine is designed to have the same per unit mutual and leakage reactance as is common for large alternators.

A synchronous generator or alternator is equipped with an automatic voltage regulator (AVR) which is responsible for keeping the output voltage constant under normal operating conditions at various load levels. The control algorithm are generally implemented using analogue component. The availability of inexpensive microprocessor has prompted a great deal attention toward digital excitation controls.[1] The improved computational speed, the smaller size, and the decreasing cost trends of micro-computer make their deployment in a dedicated control extremely feasible.

This paper describes in brief the hardware and software design of the system. Several test results of AVR using the PI and PID control on the microalternator are also presented.

II Interface Hardware design

The function of the hardware interface is to transfer the system state information to the computer and the control signals from the computer to the system. Control of the hardware interface is executed by a dedicated part of the system main computer program.

The data acquisition board acts as the interface between the digital and analogue part of the system. It contains a 12 bit ADC – ADS 574 with 8 channels, a 12 bit multiplying DAC with 2 channels, digital I/O and counter/timer facilities. The data are gathered and analysed through the data acquisition system (DAS) that was specially built for the application. The pc controlled the overall system through ADS 574 and DAC 7801. The output from DAC 7801 is connected to two firing system; firing board FC36M, to control the speed from the prime mover and module SPKC 200-240 to control the output voltage from the generator.

A. Speed Control of DC Motor

Figure 1 shows the block diagram of dc motor control. The dc power source for the motor was obtained from the silicon controlled rectifier circuit whereby its current can be regulated by using the Firing Board via a computer. The main hardware components are:

- DC Source – the dc power source for the armature used 6 silicon controlled rectifier interconnected to form a 3 phase rectifier circuit. The output from the rectifier is connected to the motor terminal through a relay which is controlled by the computer

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- Firing board model FC 36 M was used to convert the output current from the rectifier circuit. The 0-5 VDC analogue signal is derived either from the DAC or a dc signal generated manually.
- The dc power source for the field consists of a dc power source module unit with its output fixed at 205 volt. The maximum output current from this module is 1.11 Amp.

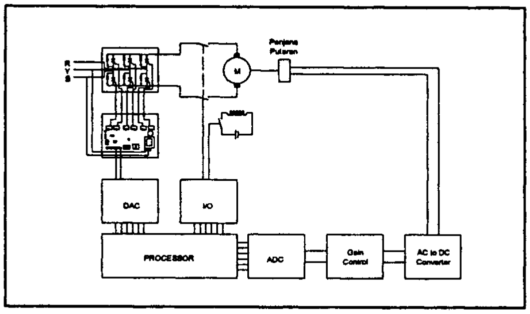

Figure 1. Block diagram of dc motor control.

B. Voltage Control of Synchronous Machine

Figure 2 shows the block diagram of voltage control of the synchronous generator. A controlled silicon rectifier is used to produce a dc source required to generate the field current. A transformer with an output of 30 volt is used to convert the line voltage and a Phase Angle Power Control Module SPKC 200-240 was used to regulate the output current from the rectifier circuit.

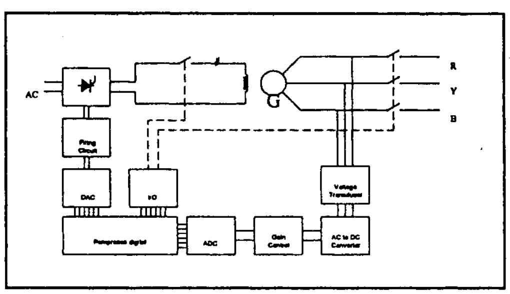

Figure 2. Block Diagram of Voltage Control For Synchronous Generator

C. Instrumentation

The parameters that are measured and monitored are the voltage, current, speed, power and power factor.

Voltage Measurement: The Hall Effect voltage transducer is used to determine the AC Voltage, DC Voltage and Impulse Voltage. In order to determine the voltage, a shunt resistor is used. The transducer output, a voltage between –5 and +5 volts, which represents a phase to phase voltage input between 64 and 330 volts, goes directly into the multiplexer of the ADC. Figure 4 shows the block diagram of the voltage measurement. The output signal from the transducer pass through several circuits; AC to DC converter, gain control and multiplexer before being fed to the ADC.

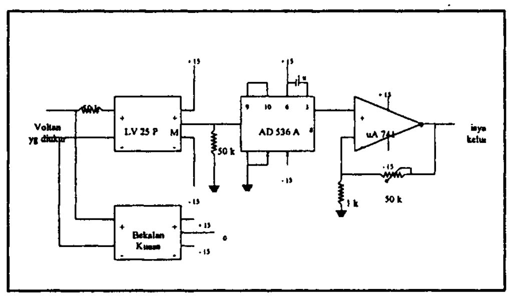

Figure 4a Signal and Gain Control Circuit

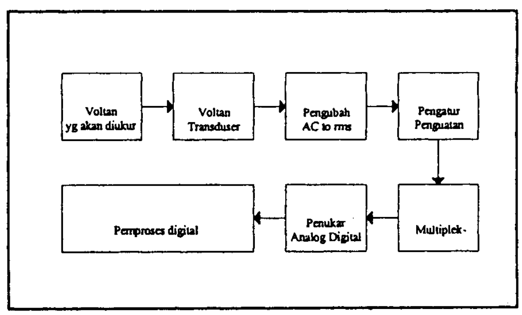

Figure 4b. Block Diagram Voltage Measurement

Current Measurement: The difference between the voltage measurement and current measurement circuit is its transducer.

Speed Measurement: The speed of the generator will generate a voltage which is proportional to the speed. The generator speed ratio is 22V/1000 rpm. The circuit is similar as the voltage measurement circuit.

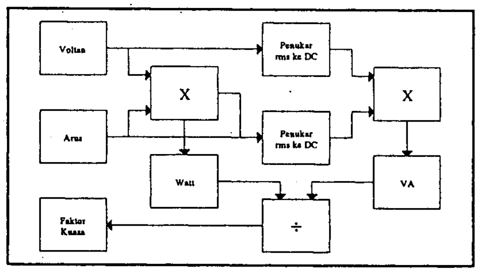

Figure 5 Block diagram of power and power factor measurement

Power Measurement: A circuit has been developed to measure the power, apparent power and power factor. (See Figure 5)

D Software Flowchart

The software used to operate and control the system is divided into 2 parts; i.e the assembler and Borland Delphi. The assembler is used to implement the command between the computer and operating hardware. The Borland Delphi was used to receive command from the keyboard, record data, visualization of the operating and control system and display of the measurements. Figures 6a-6d show the flowchart layout the overall operation of the system.

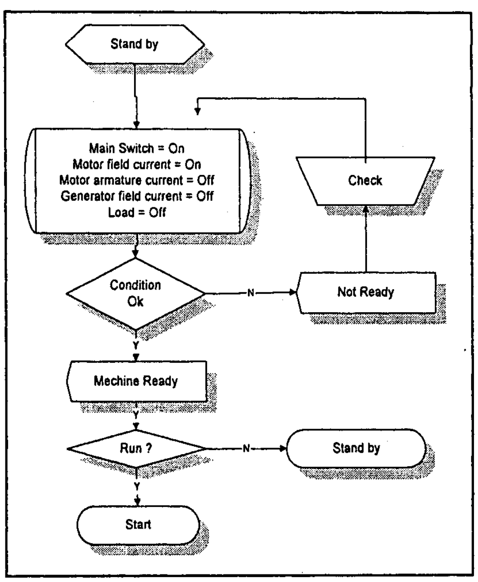

Figure 6a Flow Chart Stand by

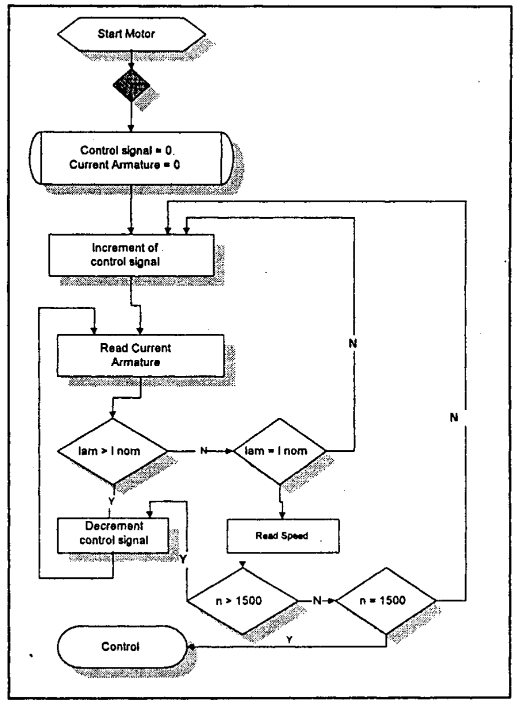

Figure 6b Start motor Flow chart

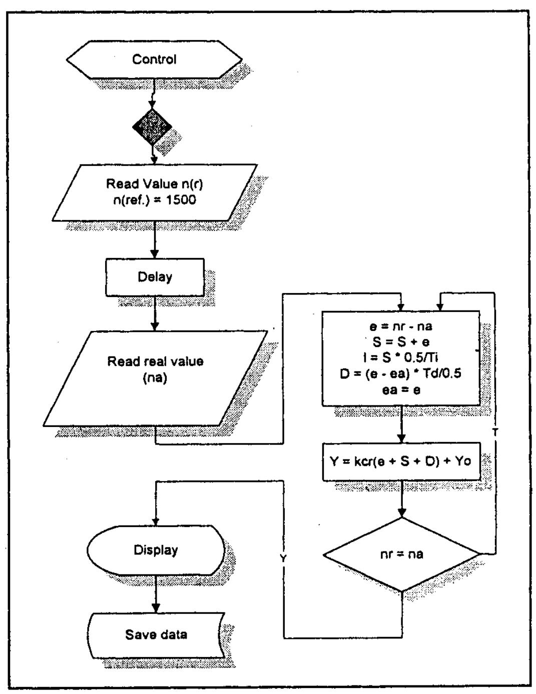

Figure 6c DC Motor control Flow Chart

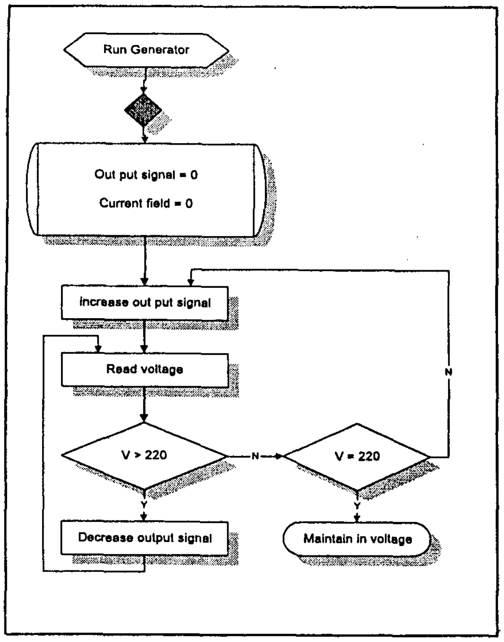

Figure 6d Generator control Flow Chart

III Implementation, Experimental Results and Discussion

Figure 7 shows the main menu screen of operation and control of the system. The microalternator can be operated either manually or automatically. To operate the system automatically, the main switch is positioned at "auto". When it is in such position, the other switches will be disabled. Activation of switches can be done only through the computer by pressing certain button as shown in fig 7.

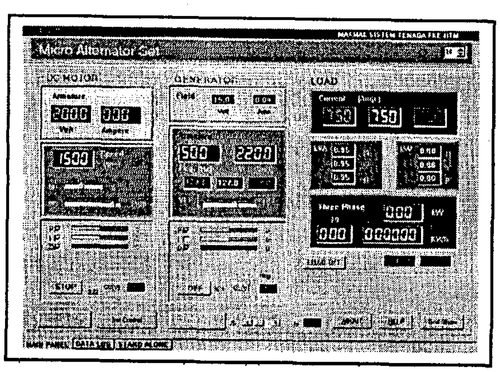

Figure 7 Control and operation main menu screen

Initially the system was tested to ensure it is ready to be operated. The field current and voltage are fixed at 1.1 amperes and 210 volts respectively. Then the armature current is increased in step until the speed of the motor remains constant at 1500 rpm. A feedback control using PID is used to control the speed of the motor such that the reference speed and actual speed is the same. The generator is ready to start. The field current is increased steadily until the voltage maintain at 220 volts. A similar feedback control is used as in the motor section.

To test the performance of the controller, the generator is loaded at 20%, 40% and 80% of the rated load. The responses for 20% of rated load (resistive, inductive and capacitive load), 40% of rated load (RLC load) and 80% of rated load (RL load) are shown in Figures 8, 9 and 10. The generator is initially run at no load and the load is applied at 50 seconds and released at 125 seconds. It is noted that the PI and PID controller always brought the generator terminal voltage to a set value. The speed of the motor remains constant when the generator is loaded since the motor is equipped with a closed loop feedback PID controller. However the motor voltage and current increases as the generator is loaded and subsequently decreases as the load is released.

Figures 8a through 8f show the response for the resistive, inductive and capacitive load at 20% rated load. The PI controller gives a better response since the system damp faster as compared to the other controller.

Figures 9a and 9b, show the response for RLC load for 40 % rated load. It is observed that there is a little overshoot in the PI controller whereas in the PID there is small oscillation. Figures 10b show that the PID controller perform better in damping out the system as compared to Figure 10a for RL load.

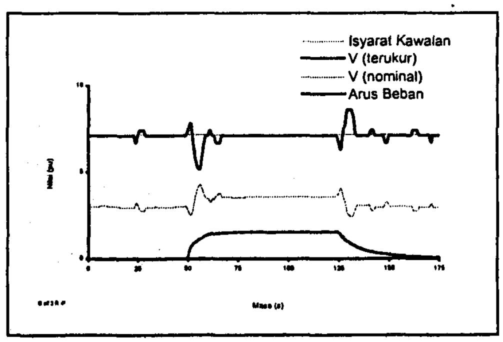

Figure 8a Generator Voltage vs Time for Resistive Load (PI)

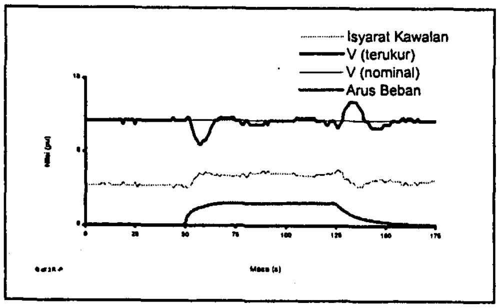

Figure 8b Gen Voltage vs Time for Resistive Load (PID)

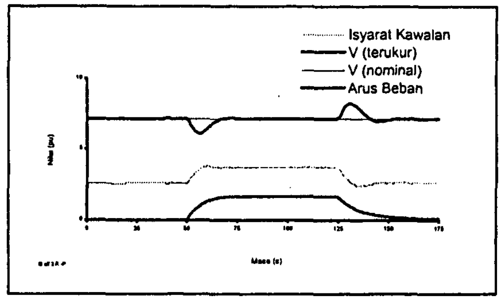

Figure 8f Gen Voltage vs Time for Inductive Load (PID)

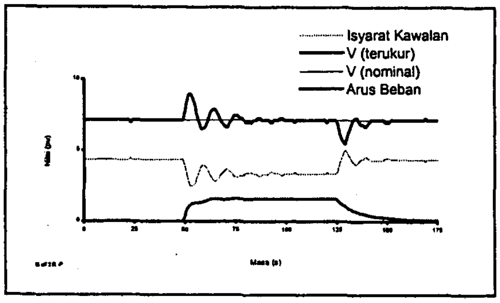

Figure 8c Generator Voltage vs Time for Capacitive Load (PI)

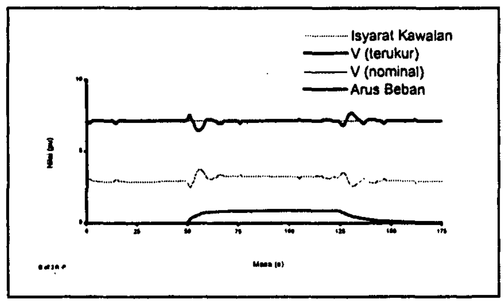

Figure 9a Generator Voltage vs Time for RLC Load (PI)

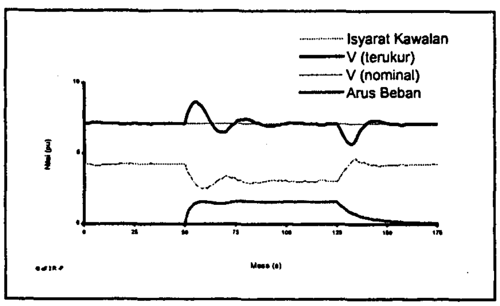

Figure 8d Gen Voltage vs Time for Capacitive Load (PID)

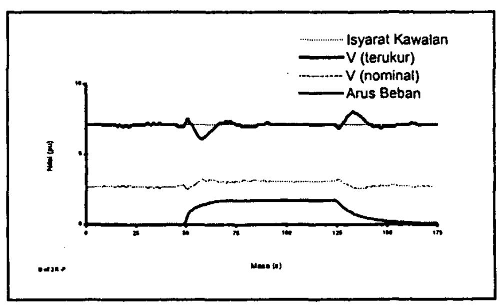

Figure 9b Gen Voltage vs Time for RLC Load (PID)

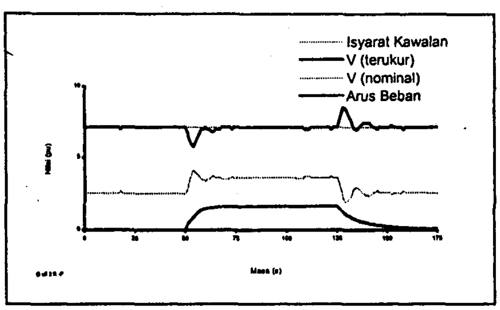

Figure 8e Generator Voltage vs Time for Inductive Load (PI)

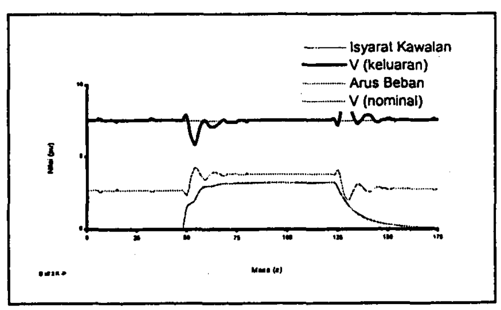

Figure 10a Generator Voltage vs Time for RL Load (PI)

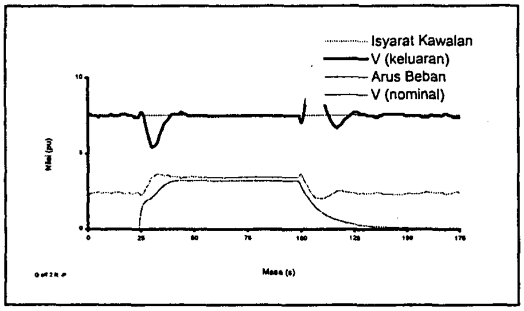

Figure 10b Gen Voltage vs Time for RL Load (PID)

IV Conclusion

With the development of the pc based controller, the system can be easily operated with ease either by using the keyboard or clicking the mouse. It also shows the feasibility of implementing the system using a dedicated pc.

From the test performance carried out, the PID controller brought the generator voltage to a set value faster with minimal overshoot and oscillation.

V References

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