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Contents

Volume 93
Issue 6
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ISSN 1726-5479

Editorial

Research Articles

Sensors & Transducers Journal, Vol. 93, Issue 6, June 2008, pp. 50-56

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Voltage Control System of a DC Generator Using PLC

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Abstract: The voltage control system of a DC generator may suffer from high frequency oscillations without offset or low frequency oscillation with offset. A PID controller can eliminate both these errors. In the present paper, the voltage control system of a DC generator using a PLC based PID controller has been designed. Operation of PLC as a continuous controller has been described and the load characteristic of DC generator with and without controller have been determined experimentally and reported in this paper. *Copyright © 2008 IFSA.*

Keywords: Feedback control system, PLC based PID control, Control parameters, Voltage control system, Tuning of controller, DC generator

1. Introduction

The output voltage of a generator [1-4] without any control mechanism is found to decrease with the increase of load current which is due to various reasons such as armature resistance voltage drop, armature reactance drop etc. This may be disadvantageous for the DC consumers in maintaining their equipments at the highest operating efficiencies. Hence the voltage regulation or control of the terminal voltage of a DC generator at a desired constant value at all loads is very important in a DC supply system. This may be achieved by controlling the field flux or the speed of the prime mover. For a permanent magnet DC generator the field flux is constant and hence the terminal voltage may be controlled by manipulating the speed of the prime mover. There may be various techniques of speed adjustment of the prime mover such as centrifugal proportional type fuel oil control, steam pressure control, hydel pressure control etc [5-8]. In the present paper a motor generator technique has been proposed in order to have a regulated supply from an unregulated system. The mode of control action of the PLC [Programmable Logic Controller] based controller [9-14] may be proportional (P), Proportional plus integral (PI), Proportional plus integral plus derivative (PID). The offset produced in the proportional controller due to load change is eliminated by the integral controller but this tends to increase the stabilization time, which may be minimized by the derivative control action. But in a very fast system such as transient process of the switching operation of a power supply system, the PI or PID control action may be excessively high enough which may lead the high frequency oscillations of the output voltage about the set point. This high frequency oscillation may be minimized by reducing the effective gain of the controller. In the case of a proportional controller the low frequency oscillation with offset may occur when a load change occurs in a plant and this offset may be decreased by increasing the gain of the controller. Many works on the design and tuning of PID controllers are being reported. Isakson *et. al.* [15] have mentioned the non-functioning of derivative control action. T. E. Ziegler *et. al*. [16] have developed optimum settings for automatic controller. In today's industrial environment, PLCs compare very favorably with other types of controllers. In the present paper the design of a PLC based PID controller has been reported. This controller has been utilized to design the proposed motor generator type DC voltage control system. The operational characteristic of the control system has been studied and the experimental results are reported in the paper.

2. Method of Approach

PID or Three-Mode Controller [10] is one of the most powerful but complex controller, where the operation combines the proportional, integral and derivative modes. This system can be used for virtually any process condition. The analytic expression is

$$P= K_p e_p + K_p K_i \int_0^t e_p dt + K_p K_d \frac{de_p}{dt} + P_i(0)\,, \tag{1}$$

where:
P is the controller output as percent of full scale;
e_p is the error of the controlled variable from the setpoint;
K_p is the proportional gain (% per %);
K_i is the integral gain ((% /s)/ %);
K_d is the derivative gain (% -s/ %);
$P_i(0)$ is the controller output at t=0.

Programmable Logic Controller or PLC is an industrial computer that accepts inputs from switches and sensors, evaluates these in accordance with a stored program and generates outputs to control machines and processes. As PLC can accept and provide discrete and analog values, the analog input and output may be current or voltage signal and PLC converts the signal to an integer between 0 and 32768 [2^{16} for 16 bit data bus] and vise versa.

The ladder diagram developed for PID control using PLC Software is shown in Fig. 1. In the diagram each rung consists of different functional blocks and output from each block is stored in registers addressed as % R0000N where N is register number. Power flows from left side to right side. After execution of 1st rung one analog input (set point value) is entered in to PLC processor through IN terminal (INPUT 2), which is an integer in between 0 to 32786 depending on the magnitude of the input signal. This integer value is converted in to a real number for appropriate scaling which is done by "INT TO REAL" and "DIV REAL" function blocks. After appropriate scaling the real value output is again converted into integer value by "REAL TO INT" function block and stored in Register whose address is %R00008. Similarly the measured value or process value i.e. another analog input goes to PLC after execution of 3rd rung and is stored in register address %R00014. PID control operation is performed in rung 2 by PID ISA function block where set value (SP) and process value (PV) are coming from %R00008 and %R00014 respectively. In PID ISA function block "MAN", "UP" and "DN" terminals are always off (ALW_OFF) for automatic operation. Controlled variable (CV) is stored in %R00015 that is an integer and can be again scaled in rung 4. The content of the register %R00015 will go to the analog output terminal of PLC to be fed to the appropriate output device.

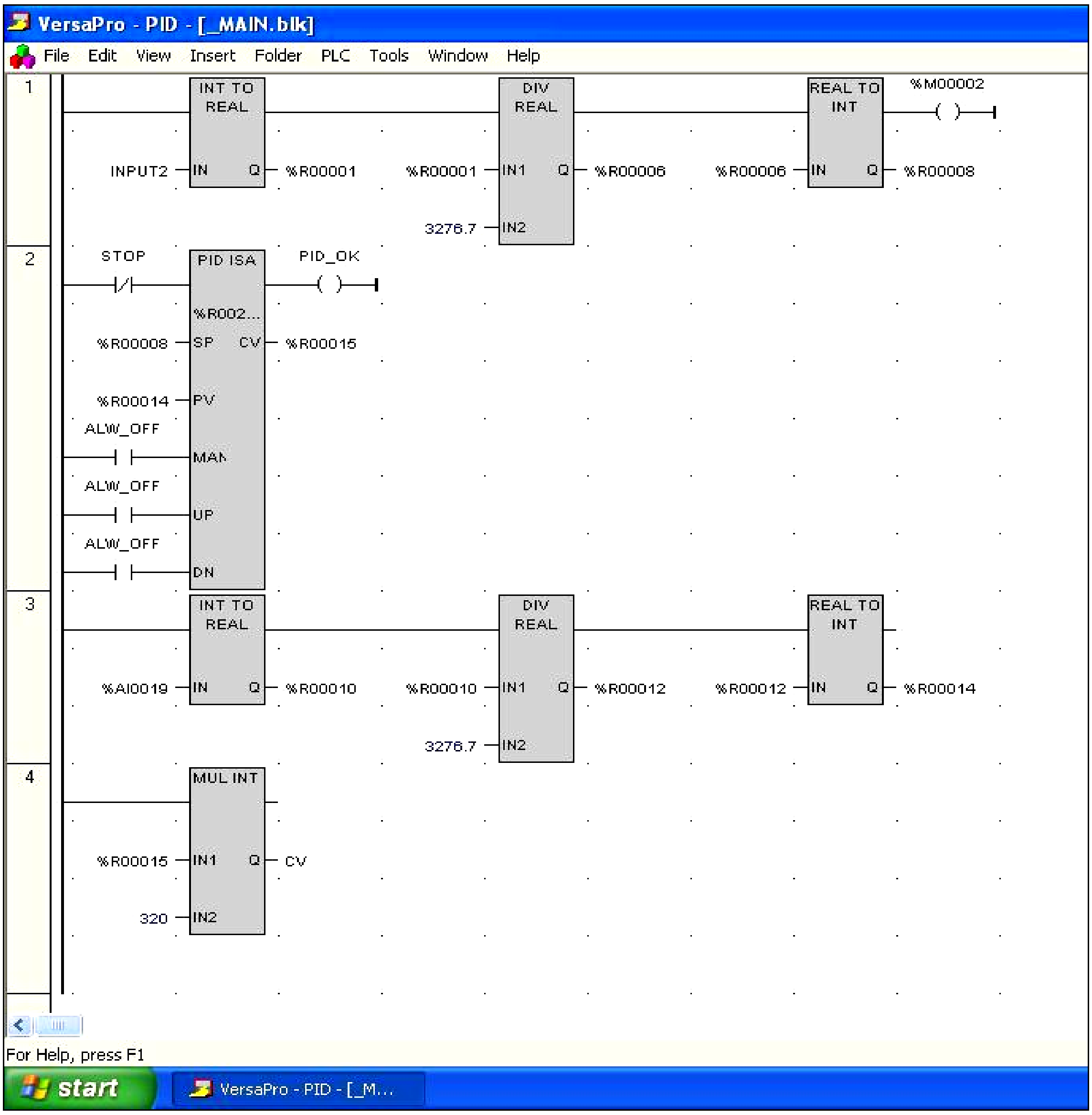

Fig. 1. Ladder diagram for PID control using VersaPro software.

Tuning of controller [9-13] is the process of setting gains to achieve desired performance. The tuning sets the loop gains by optimizing the response to the command. Higher loop gains will improve command response and they also improve the disturbance response. In PLC based PID controller provisions are there to set the tuning parameters such as controller gains and can be viewed the corresponding controller output. Set point value (SP), Process Value (PV) and controlled variable (CV) - all are clearly observable during tuning and thus gain setting is very easier in this system. The typical controller-tuning window for tuning of PLC based PID controller is shown in Fig. 2.

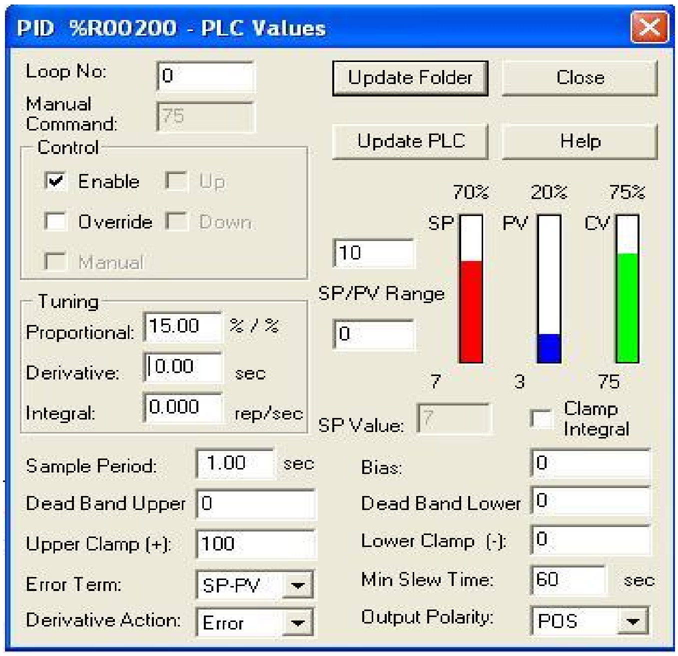

Fig. 2. Controller Tuning Window.

From the Fig. 2, it is clear that proportional gain, derivative gain, and integral gain can be set by the user and variation in set point (SP), process variable (PV) and controlled variable (CV) all will be observed from the same window.

3. Design

The proposed motor-generator type DC voltage control system has been designed according to the block diagram as shown in Fig.3.

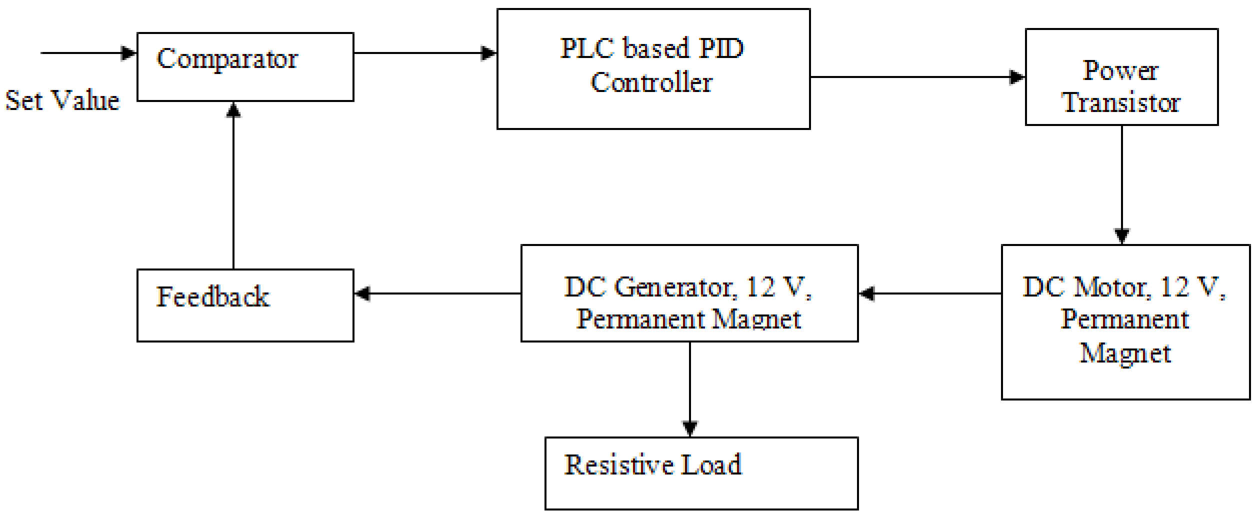

Fig. 3. The block of the proposed motor-generator type DC voltage control system.

In this system the generator and the motor are selected to be small DC type so that the proposed PLC based controller may be directly used avoiding high cost of a large capacity buffer unit. The output voltage of the generator is compared with the set point or desired value by the controller and the controller output is accordingly varied when there is a deviation. This controller output voltage is used as the armature voltage of a low voltage permanent magnet type DC motor through a buffer transistor. Hence the speed of the motor is adjusted until the deviation is reduced to zero and the generator output voltage is maintained at the desired value.

4. Experiment

This PLC based PID controller has been utilized to design the voltage control system of a DC generator as described above. The experiments are performed to determine the V–I characteristics of the DC generator without and with controller. The V-I characteristic graphs for generator without controller and with controller are shown in Fig.4 and Fig. 5 respectively. The variation of output voltage at different set points at given load is shown in Fig. 6.

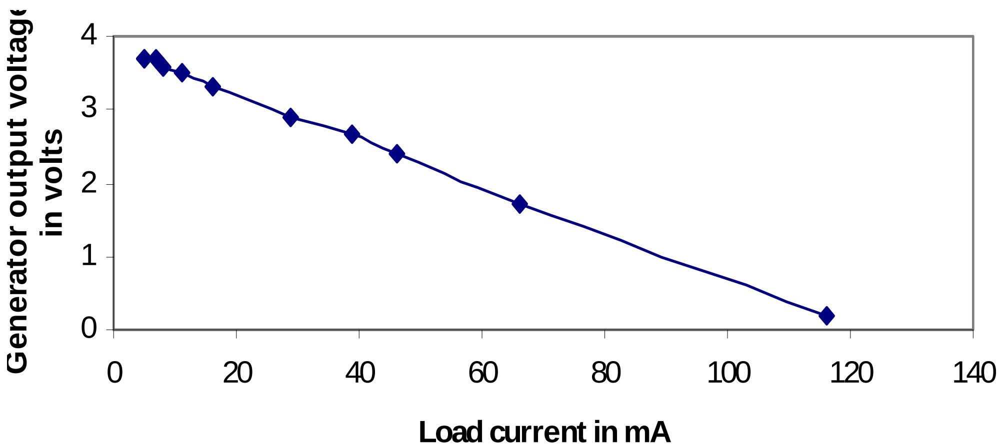

Fig. 4. V – I characteristic of DC generator without controller.

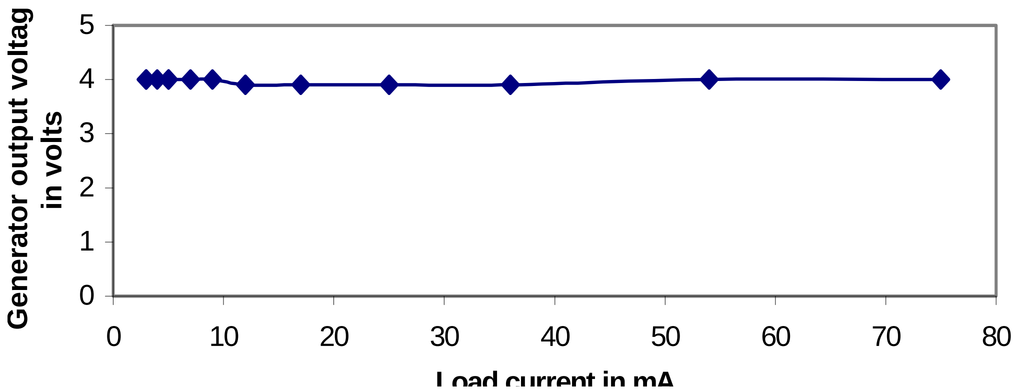

Fig. 5. V – I characteristic of DC generator with controller.

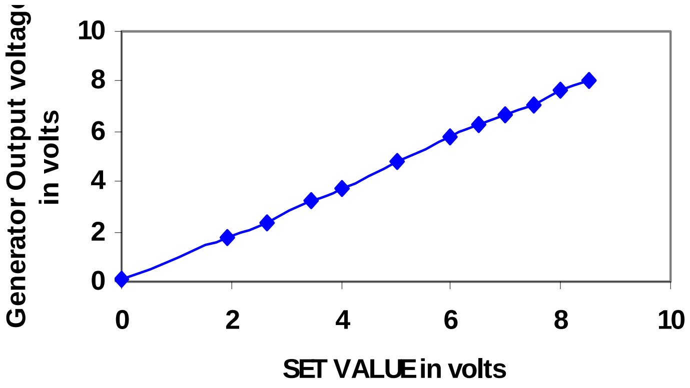

Fig. 6. Variation of DC generator output voltage with set point.

5. Discussions

From the experimental results shown in Fig. 5, it is observed that the output voltage of the DC generator is maintained almost at a constant value under all dynamic conditions of the load. The variation of the generator output voltage with set point as shown in Fig. 6 is found to be quite linear. More accurate results may be obtained by following the proper tuning criteria of the PLC based PID controller.

A few key characteristics make the PLC advantageous over other controllers. Firstly, PLC is designed to communicate directly with the process to be controlled and PLC recognizes these inputs and outputs as part of its system at a fixed address. Secondly programming and reprogramming is much easier with PLC based controller. Thirdly such types of controllers are designed to operate in demanding industrial environment such as high noise, high vibration, high temperature, and high humidity. These three factors are largely responsible for the wide acceptance of PLC as controller. They require no special programmer; no air conditioned rooms and no special input output systems to be designed.

This PLC based voltage control system will be highly useful to control the external excitation of an alternator and synchronous motor in power plant and industries.

References

[1]. Mihai Comanescu, Ali Keyhani, and Min Dai, Design and Analysis of 42-V Permanent-Magnet Generator for Automotive Applications, *IEEE Transactions on Energy Conversion*, Vol. 18, No. 1, March 2003.
[2]. R. Cardenas, R. Pena, G. Asher and Clare J., Control Strategies for Enhanced Power Smoothing in Wind Energy Systems Using a Flywheel Drive by a Vector-Controlled Induction Machine, *IEEE Transaction on Industrial Electronics*, Vol. 48, No. 3, June 2001, pp. 625-635.
[3]. V. N. Nandakumar, K. Yadukumar, T. Sureshkumar, S. Ragupathi, and R. K. Hegde, A Wind Driven Self-Excited Induction Generator with Terminal Voltage Controller and Protection Circuits, *IEEE Power Conversion Conference*, 1993, pp. 484-489.
[4]. B. K. Bose, Modern Power Electronics and AC Drives, *Prentice-Hall*, NJ, 2002.
[5]. D. Seyoum, C. Grantham and F. Rahman, Analysis of an Isolated Self-Excited Induction Generator Driven by Variable Speed Prime Mover, *Proc. AUPEC'01*, 2001, pp. 49-54.
[6]. S. Huang, J. Luo, F. Leonardi, and T. Lipo, A general approach to sizing and power density equations for comparison of electrical machines, *IEEE Trans. Energy Conversion*, Vol. 34, March 1998, pp. 92–97.
[7]. D. C. Hanselmann, Brushless Permanent Magnet Motor Design, *McGraw-Hill*, New York, 1994.
[8]. M. A. Alhamadi and N. A. Demerdash, Modeling and experimental verification of the performance of a skew mounted permanent magnet brushless DC motor drive with parameters computed from 3D-FE magnetic field solutions, *IEEE Trans. Energy Conversion*, Vol. 9, March 1994, pp. 26–35.

[9]. D. E. Rivera, M. Morari, S. Skogestad, Internal model control. PID controller design, *Ind. Eng. Chem. Process Des. Dev.*, Vol. 25, 1986, p. 252.

[10]. Ogunnaike, B. A., Ray, W. H., Process dynamics, modeling and control, *Oxford University press*, New York, 1994.

[11]. T. E. Marlin, Process Control, *McGraw - Hill*, New York, 1995.

[12]. Doglas M. Considine, Process Instruments and Control Hand Book, 2nd edition, *McGrawHill Company*, 1974.

[13]. Bela, G. Liptak, Process measurement and Analysis, 3rd edition, *Butterworth Heinman Ltd.*, 1999.

[14]. C. Johnson, Process Control Instrumentation Technology, 4th Edition, *Eastern Economy Edition*, PHI. 1997.

[15]. A. J. Isaksson, S. F. Graebe, The derivative filter is an integral part of PID design, *Presented at Control Systems 2000*, Victoria, British, Coloumbia, May 2000.

[16]. T. E. Ziegler, N. B. Nichols, Optimum settings for automatic controller, *Trans. ASME*, Vol. 64, 11, 1942, pp. 759–768.

Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually.

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Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

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- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
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- Technologies and materials;
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