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DIGITAL CONTROLLER FOR DIESEL ENGINES

Currently produced generators are based on diesel engines. An engine speed is controlled by a centrifugal governor, which works satisfactorily practically only at high speed (3000rpm). High revolution operation causes high emission of pollution and low safe life of a generating set. The electronic controller has been developed that maintains speed of 1500rpm. Time between pulses coming from a geared flywheel is a value being controlled. Linear electromagnet is used as an injection pump actuator. Tests made at engine test bench confirmed the possibility to down-speed an engine maintaining permissible voltage and frequency deviations.

1. Introduction

Diesel engines are characterised mainly by high power at low revolutions, at he same time a power vs. revolution speed characteristic is flat. Apart from the commonly known automotive application, these qualities predestine diesel engines to be applied in various branches of industry, especially where the very hard operation conditions may be met.

One of such applications is power generation. Variable load, open-air operation sometimes at heavy weather conditions originate a necessity to design an electronic alternative to the common rotation speed controllers for such engines. Until now generator units were equipped with a centrifugal governor, which works satisfactorily practically only at relatively high, as for diesel engines, rotation speed (3000rpm). Low reliability and low controllability stimulate Polish companies to search for new designs. The aim of the research is to speed-down an engine twice (1500rpm), what should result in longer MTBF (mean time between failures) what means lower exploitation costs as well as in making such set more ecological.

The response is the digital controller for diesel engines developed in Department of Electronics of the Lublin University of technology. Two design criterions were assumed: output frequency should be 50Hz with a tolerance 0 to 4% and the settling time should be shorter than 1s. Additionally an oil temperature inside oil sump and cooling medium temperature are monitored. We plan to design a module that analyses “health” of generator set in the future.

2. design of the controller

The controller consists of three modules. An industrial inductive revolution sensor is the first one. It counts pulses coming from a flywheel mounted on engine’s shaft that transmits drive torque from a starter. The flywheel has 100 teeth so at 3000rpm we get 300000 pulses per minute i.e. 5000Hz.

A cut-off frequency of a vast majority of commercially available inductive revolution sensors is about 3kHz, so finding the transducer of nearly double cut-off frequency has been a problem. When a transducer operates close to its cut-off frequency regeneration of output signal may be necessary. It is being done using a comparator without hysteresis. The signal is then TTL conditioned and fed into a processor.

The processor with input/output signal-level matching circuits as well as a power supply constitute another module. It is depicted at fig. 1.

The Atmel AT89C5 controller from 8051 family has been used in the controller. It has an advantage of integrated flash memory, what definitely simplifies external hardware needed and also reduces the risk of malfunction due to external disturbances. The controller implements software PID control scheme. Time between pulses is an input value for control. This time allows determining rotation speed of engine’s crankshaft. Pulse width of repetition frequency of 300Hz is an output signal. The PID parameters (k_p, k_i, k_d) were adjusted experimentally using Ziegler – Nichols metho*d. It gave good results, the controller is stable and its settling time as a response for a step function is shorter than 1s.

The calculated output signal is fed into a driver (IR2110). It has to properly switch-on the transistor (IRFZ44) for keying of electromagnet. The selection of the driver has been determined mainly by switching speed. Typical switch-on and switch-off times are 120 and 94ns respectively. A time between consecutive changes of driver's output is typically 10ns. The keying transistor has been selected mainly for its low turn-on resistance of 24mΩ, what corresponds to drain current up to 50A at corresponding temperature. The transistor is protected with a Shottky diode, what is a very important issue when switching an inductance.

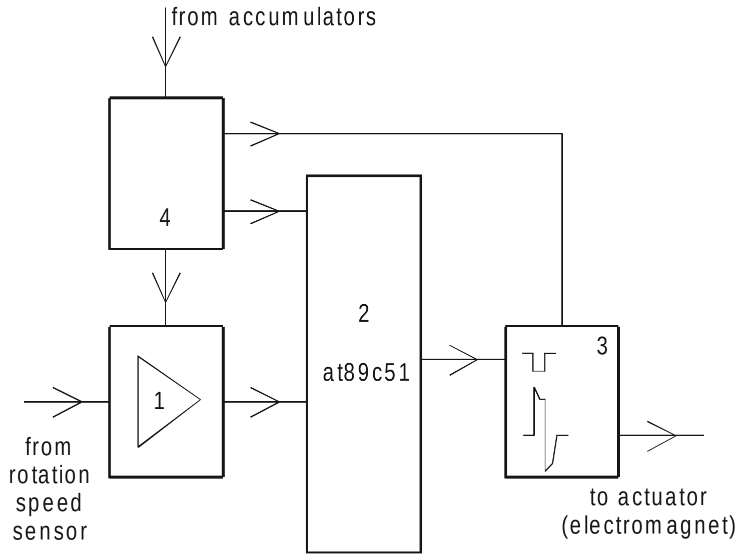

Fig. 1. Controller module. 1–pulse regeneration circuit; 2–microcontroller; 3–driver with keying transistor; 4–power supply

The switched-mode power supply is an important component of this module. It maintains 5V of output voltage at very wide range of input voltages between 4V and 15V. It allows avoiding consequences of external disturbances like engine start-up. The keying transistor itself is supplied directly from accumulators.

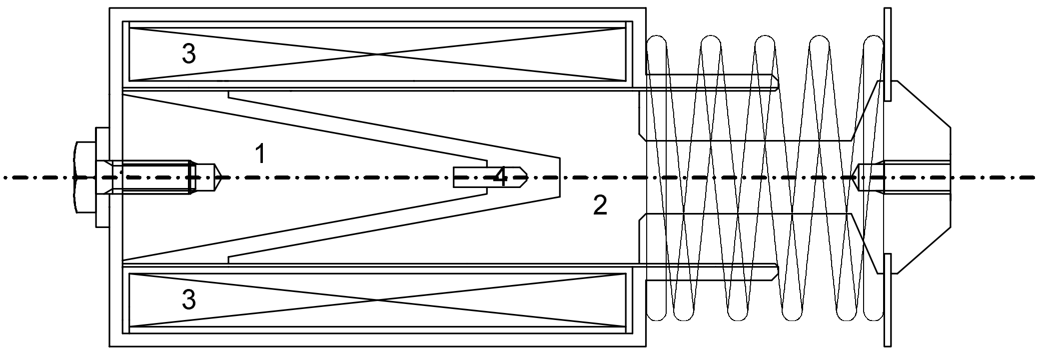

Fig. 2. Cross-section of electromagnetic actuator: 1–cone; 2–movable core; 3–winding; 4–Teflon spacer

Electromagnet actuator is the third module. It is assembled right on engine's body and directly moves injection pump control lever. Many problems appeared during design of this component. First, there

* *Kaczorek T., Teoria sterowania i systemów, , PWN, Warszawa 1999, 801 pp. ISBN 83-01-12072-X.*

is a lack of commercially available electromagnetic actuators with linear dependence of force on winding current. Secondly the resistance to the high temperature and it's rapid changes (engine warm-up). Resistance to the external conditions like humidity or dustiness also plays an important role. An actuator has also to be compact and easy to assemble. It has been necessary to design the special electromagnet meeting the above conditions. Its cross-section is shown at fig. 2.

A linear dependence of force on winding current has been achieved by placing a properly shaped cast steel cone at the bottom of casing. The value of a current is settled by PWM. A linear dependence between an effective value of the current and force acting on the magnet core results in its linear displacement. A dependence of force acting on the core on its position is depicted at fig. 3. It shows that it can be assumed that useful range of displacement lies between 8mm and 38mm. The Teflon spacer has been placed on the tip of the cone to avoid sticking with the movable part.

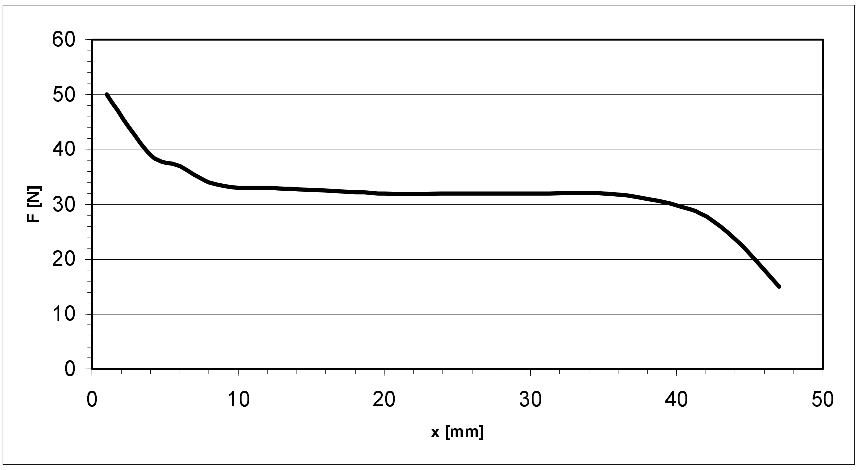

Fig. 3. Dependence of force acting on the core on its position

The temperature resistance is achieved by zinc plated metal casing with numerous radiation elements, they increase a thermal inertia of the whole electromagnet. The temperature inside varies very slowly and stabilises itself at the level of 50°C. A rubber gaiter protects movable parts against getting dirty. The interior of electromagnet is coated with Teflon so there is no need of greasing.

3. Measurements

Currently the controller is being submitted to the dynamic load trials made at engine test bench. An example response chart is shown at fig. 4. A variable, dynamic electrical load obtained by connecting of various electrical appliances is an input value, while frequency of generated power is an output. The data has been obtained by a computer data acquisition board.

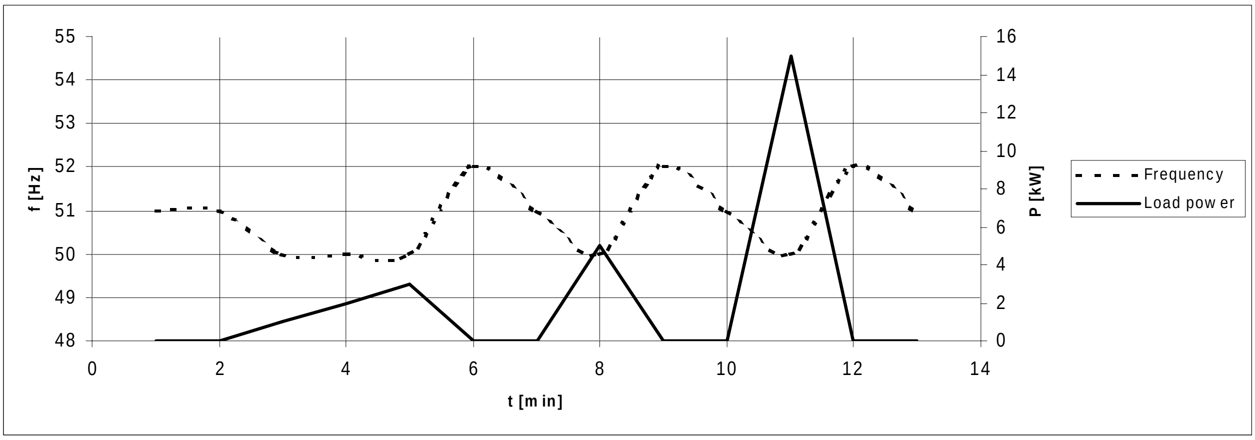

Fig. 4. Input-output chart of a controlled generator set

In order to meet frequency restrictions (50Hz, –0%, +4%) the idle run frequency equal to 51Hz has been chosen. Therefore deviation is ±1Hz. It can be seen that these conditions are met for wide range of electrical load and for such heavy disturbance as switching on 15kW of load. Long term and environmental tests are still to be done. We also plan to install thermal sensors for monitoring and self-diagnostics of the entire generator set.

4. Conclusions

The designed digital controller meets the requirements. Down-speeding from 3000rpm to 1500rpm results in higher durability and longer MTBF what has direct economical advantage. At the same time new possibilities of such controller arise like monitoring and self-diagnostics of the entire generator set. The controller has a chance to become a commercial product.

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ASSESSMENT OF PULVERISED COAL AND SECONDARY FUEL MIXTURES COMBUSTION USING IMAGE PROCESSING

Air stepping, which takes place in pulverised-coal burners, makes combustion less stable. Such a situation may lead to shifting the flame, unstable combustion and eventually to extinguishing of the flame. Adding secondary fuels such as waste fuels and biomass spoils combustion stability and leads to increasing corrosion and boiler slagging. Spatial distribution of radiation intensity (flame shape) and its changes in time domain deliver the quickest and straight information of combustion process itself. We have utilised flame images taken by CCD camera in a several combustion tests to find flame shape features, which would point a state of unstable combustion.

1. Introduction

The new regulations concerning the maximum allowable emission of harmful substances such as nitric and sulphuric oxides (known as NOx and SOx respectively) have given rise to disseminate new combustion techniques. Polish power industry is based mainly on hard coal, thus so called low-emission combustion of pulverised coal is of great importance. Low-emission combustion consists in the proper manipulation of fuel and air so as to create rich and poor flame zones which differs in oxygen content. It enables both synthesis narrowing and reduction of the formed nitric oxides. [1]

Air stepping, which takes place in pulverised coal burners, makes combustion less stable. Worse stability is caused by the shortage of oxygen in the area placed close the burner nozzle. Such a situation may lead to shifting the flame, unstable combustion and eventually to extinguishing of the flame.

One of the main objectives of this work was comparison of the ignition and combustion behaviour of different secondary fuel/coal mixtures in turbulent flame using CCD camera.

Combustion tests were performed in 0.5 MW_{th} laboratory stand at the Institute of Power Engineering. It enables scale down (10:1) combustion conditions of a full-scale swirl burner fired with pulverised fuel.

The stand was fired with milled secondary fuel – coal mixture samples. The samples were prepared and supplied by Stuttgart University (IVD) and International Flame Research foundation (IFRF BV) as well as taken from pulverised coal ducts during co-combustion tests at Łagisza power plant in Poland. Several fuel samples were investigated, namely reference hard and brown coals and these coals mixed with wood and paper sludge.