Control of small gasoline genset

Ing. Adam Kouba
Supervisor: Prof. Ing. Ivan Uhlíř, DrSc.

Abstract

In this paper were examined static and dynamic characteristics of small gasoline genset ASIST AE 8G95-F with nominal power 650W @ 3000 rpm. Rotational speed fluctuation of crankshaft in various genset modes was the main measured parameter. Even if the rotational speed fluctuation was higher than 1% which is thought as common limit (measured fluctuation was from 1.5% to 3%), it's fully corresponding in use for small gasoline gensets. Small inertia mass of rotor could be taken as advantage in emergency case, but together with a poor quality of mechanical pendulum controller it causes large drops of rotational speed after higher load steps. In ground of unit, there is no feedback control of output voltage. Because of self-excited rotor of alternator without slip rings, there is no way how to simply add feedback control. The main target of this paper is to replace mechanical pendulum controller with new actuator and electronic controller. Paper is based on my bachelor thesis [5] which is extended with acknowledge and new solutions related to trends of researched issue, which author aims to heavy duty engine diagnostics.

Keywords

Rotational speed fluctuation, control, gasoline, genset, ASIST AE 8G95-F

1. Introduction

Paper deals with technical resources used in electronic rotational speed control of small gasoline genset ASIST AE 8G95-F of nominal power 650W @ 3000 rpm. The main target is to review current solution of control of small gasoline genset and to measure load and control parameters of genset. Afterwards the paper deals with possible improvements of control parameters by application of electronic control, respectively with a replacement of mechanical pendulum controller with new actuator and electronic controller.

1.1 Analysis of available solutions

In recent years manufacturers are trying to force prices of genset down not only with help of cheap labor force of east world, but they are also looking for solutions with cheaper materials or technologies. It's not a surprise that in case of small gasoline gensets, for which is this trend the most obvious, nonstandard solutions of output voltage control are used by manufacturers. In case of small low-end gensets mechanical rotational speed control with pendulum is used. In middle class gensets, electronic speed control is used (actuator and sensor of rotational speed) and the output voltage is controlled via slip rings. The most precious high-end gensets are nowadays moreover equipped with voltage converter and capacitor, which is not so expensive in case of gensets with nominal output up to 15kVA. These gensets are also running on higher speeds (4000 rpm to 5000 rpm) with multiplied number of poles to achieve higher frequencies, which yields to reducing of necessary capacitor size.

1.2 Output voltage control of small low-end gensets

Researched low-end genset offers output voltage solution which is affected by requirement for the lowest price. This solution fully depends on quality of rotational speed control loop.

Rotor is formed from two separated windings and it's excited by electronic circuit, which is situated directly on rotor. So there is no need to add problematic slip rings to feed rotor by current. Disadvantage of the solution is that in this case, rotor circuit is not equipped with feedback control loop and the output is only feedforward control of effective value of output voltage. The error of effective output voltage value is given by calibration and accuracy of electronics components, which are situated on self-excited rotor and by quality of speed control loop. In case of researched genset, modifications leading to voltage control loop would be too difficult, that the price of these changes would be higher than the price of ASIST genset.

1.3 Speed control of small low-end gensets

Control of small ASIST genset is reduced to only rotational speed control because of reasons presented in previous chapter. The most common solution of speed control of low-end gensets is application of mechanical controller. This solution is also used on ASIST genset, where the 2-stroke engine with nominal speed 3000 rpm is controlled by actuating throttle valve on carburetor intake with feedback of mechanical pendulum. In case of higher speed, pendulum is more affected by centrifugal force and it starts to close throttle valve which yields to lower engine power and speed, the same principle is used for opposite case. This solution unfortunately yields to high difference between engine speeds in low loads and high loads. Difference between low load and high load speed could be up to 5%. That is such a big value because of impact on dependent voltage feedforward control.

2. Measuring of speed and voltage control parameters

Rotational speed fluctuation and parameters of control, torque and power were measured on ASIST genset, by using methods from [2], [3] and evaluation from [1]. Some of measured results are shown in diagrams further in this chapter.

2.1 Load diagrams

Due to poor quality of mechanical control of researched genset, there was a permanent control error from desired value of 3000 rpm. For low loads, rotational speed was higher than desired and for high loads the rotational speed was lower than 3000 rpm. Because the effective value of output voltage is dependent on genset speed, same effect was significant in case of it. Both characteristics are shown on figure 1 and figure 2.

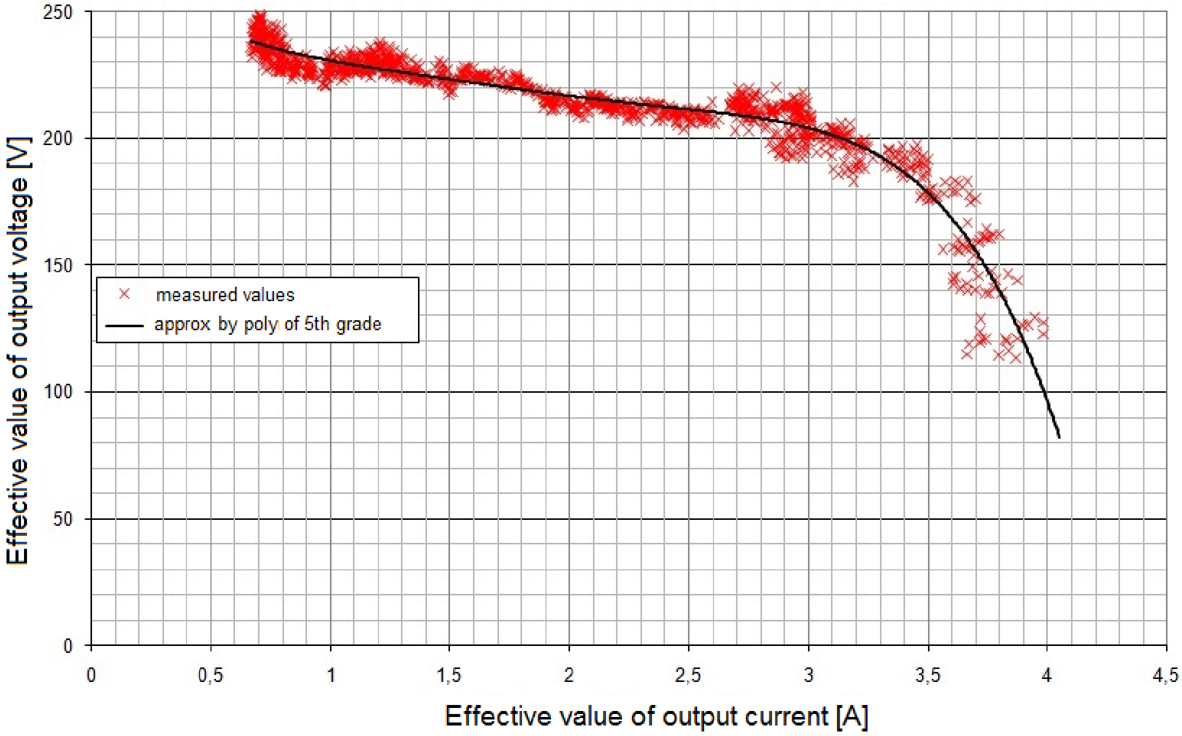

Figure 1: *effective value of output voltage vs. effective output current - with original mechanical pendulum controller*

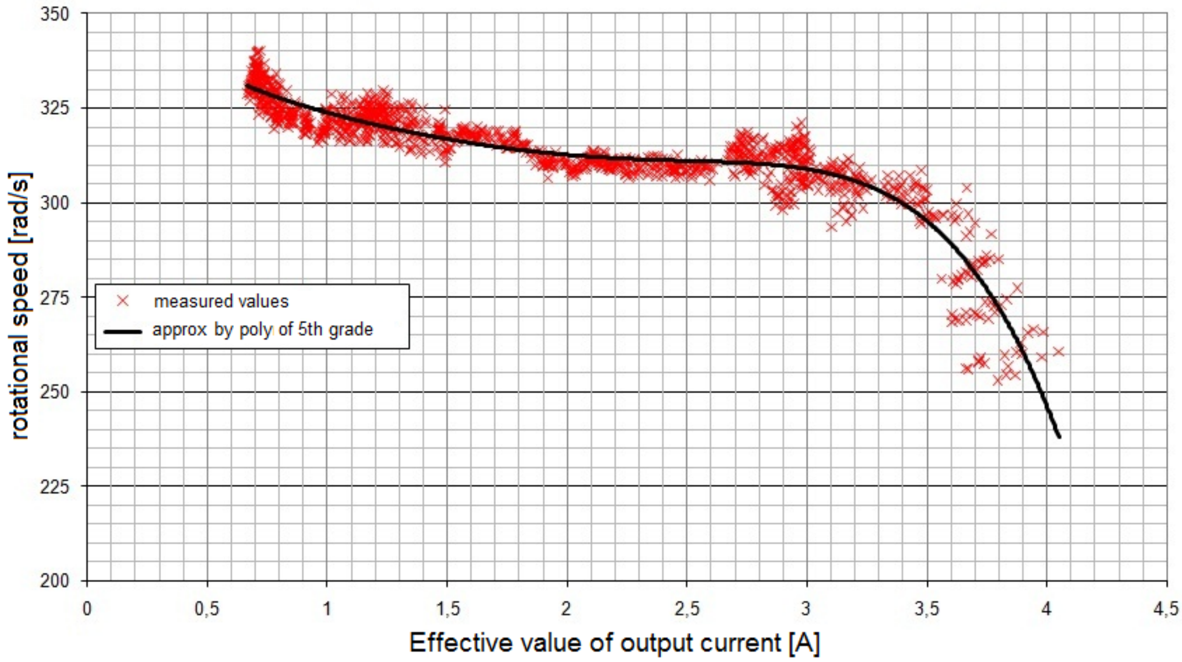

Figure 2: *Rotational speed vs. effective output current - with original mechanical pendulum controller*

2.2 Measuring and analyses of rotational speed fluctuation

Speed voltage generator K4A2 of MEZ NÁCHOD manufacturer was used to measure rotational speed fluctuation. Sensor was mounted on the side of alternator and connected with a genset rotor. We can define rotational speed fluctuation N as the difference between highest and lowest peak value during one crankshaft (rotor) rotation. We can write this as in equation 2.1. The percentage error of rotational speed δ can be calculated as in equation 2.2.

$$N = \left|\min\left(\delta(t_p)\right)\right| + \left|\max\left(\delta(t_p)\right)\right| \tag{2.1}$$

$$\delta(t) = \frac{\omega(t) - \omega_s}{\omega_s} \cdot 100 \tag{2.2}$$

The value of rotational speed fluctuation is dependent on load. Comparison between fluctuations with two different loads is shown on figure 3 and 4. In idle there is a bigger problem speed control than rotational speed fluctuation. For small gensets as ASIST is the higher value of rotational speed fluctuation given by small inertia mass of rotor and by using of a 1 cylinder engine (2-stroke). On figure 5 speed fluctuation in dependency on genset load is shown.

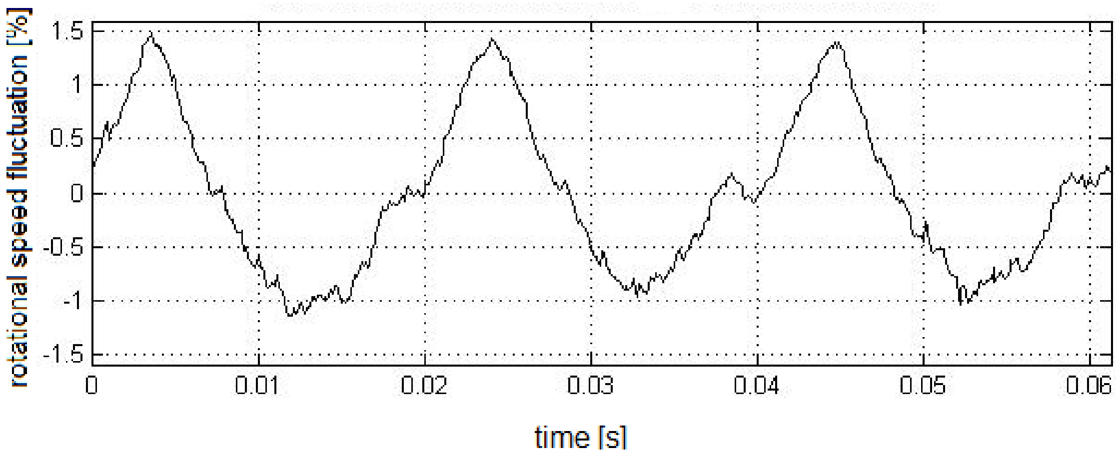

Figure 3: *Rotational speed fluctuation of genset – load 670W @ 3000rpm*

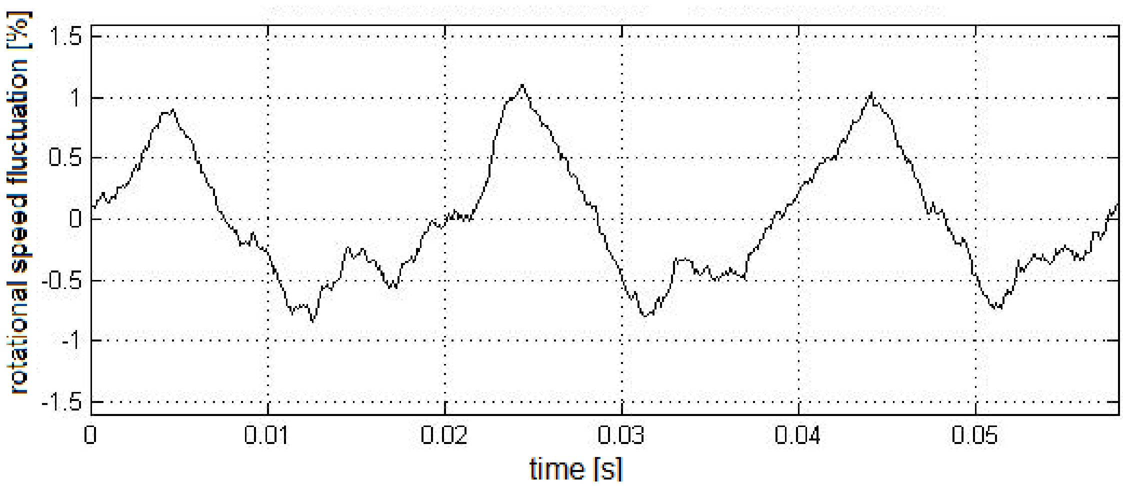

Figure 4: *Rotational speed fluctuation of genset – load 270W @ 3000rpm*

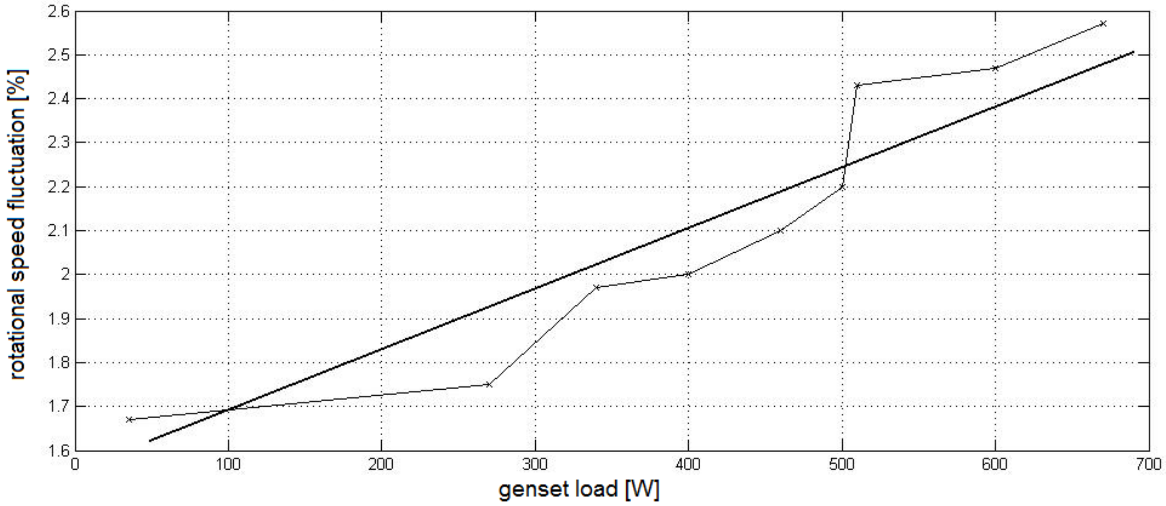

Figure 5: *Rotational speed fluctuation vs. genset load @ 3000rpm*

2.3 Output voltage control

As it was said beforehand, output voltage control of ASIST genset is designed with self-excited diode circuit which is situated on rotor. This fact affects accuracy of output voltage and cause a deformation of output voltage sinusoid. Higher load cause higher deformation of sinusoid, this deformation is shown on figure 6.

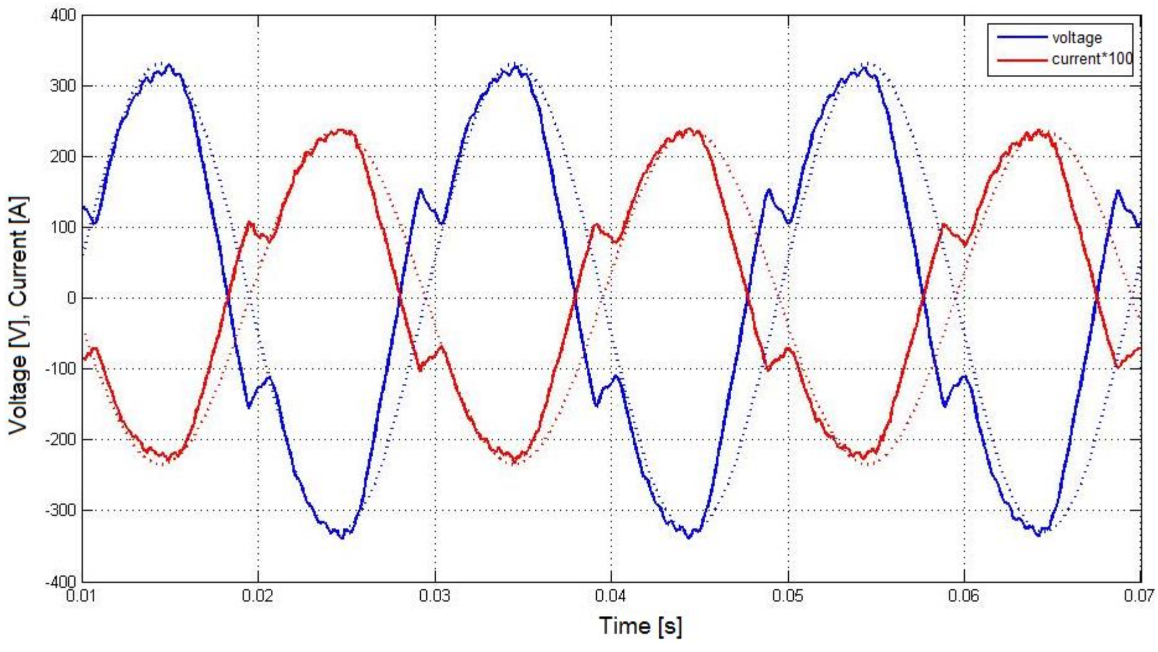

Figure 6: *Output voltage and output current vs. time - load 350W @ 3000rpm*

Possible improvement to increase accuracy of output voltage control is to use a capacitor and frequency converter at the output of genset. This solution eliminates rotational speed fluctuation, speed control inaccuracy and deformation of output voltage sinusoid on the output of genset.

3. Results

Reconstruction based on replacement of mechanical controller by electronic actuator was made. Futaba S3001 analog servo was used as electronic actuator. Actuator was mechanically coupled with throttle valve. Control impulses of servo were generated in LabVIEW software and measurement and automation device LabJack U3-HV. Simultaneously PI controller was created in LabVIEW. Coding and calibration of genset PI controller in LabVIEW is described in [4]. Reconstruction of genset control didn't give us hoped improvement in genset technical parameters.

1. Permanent control error was reduced by PI controller. Different engine speed for different loads was also eliminated, but the response of control to step change of load was slow, approximately 3 seconds. This problem was given by slow response time of actuator. Dominant time constant of actuator was approximately 1 second, but the time constant of controlled system was due to small inertia masses of rotor under 0.5 second.
2. Voltage control wasn't modificated, so there was still a poor quality of control without control feedback. To improve voltage control there was a need to add slip rings and brushes to the rotor, but the cost of this modification is more expensive than cost of ASIST genset which is around 2000 CZK, so it was a nonsence to do this modification.

4. Conclusion

The conclusion of this work is that there is no simple way how to improve technical parameters of simple low-end gensets only by adding electronic controls of rotational speed and eventually a control of output voltage. Possible improvement of genset with original voltage and speed control is to add rectifier with large capacitor to feed frequency converter. Large capacitor will deliver impulse during high step of load and the frequency convertor will produce high-quality sine voltage with required effective value.

Nomenclature

ω_s	Averaged rotational speed	[rad/s]
ω	Rotational speed	[rad/s]
t	Time	[s]
N	Rotational speed fluctuation	[%]
δ	Difference between ω and ω_s	[%]
t_p	Period of one crankshaft rotation $\mathrm{t_p} \in (\mathrm{t_{1p}}; \mathrm{t_{2p}})$,	[s]

References

[1] Macek, J. *Spalovací motory I.* Praha: Vyd. ČVUT, 2007. ISBN 978-80-01-03618-1.2]

[2] Takáts, M. - Uhlíř, I. - Novák, L.: *Running Roughness Measurement - Tools for Development and Diagnostic. In: 23rd CIMAC Congress Proceedings*. Frankfurt am Main: CIMAC, 2001, vol. 1, p. 1340-1348.

[3] Takáts, M. - Uhlíř, I. - Novák, L. - Miffek, K.: *Analýza úhlové rychlosti otáčení klikového hřídele.* In: KOKA 2000. Žilina: Žilinská univerzita, 2000, s. 105-110. ISBN 80-7100-736-6.

[4] Kozák, O. *Návrh a realizace regulátoru benzínového agregátu v prostředí LabVIEW.* Bakalářská práce, ÚPŘT, FS-ČVUT v Praze, Praha, 2010.

[5] Kouba, A. *Elektronická regulace otáček malého benzínového agregátu.* Bakalářská práce, ÚPŘT, FS-ČVUT v Praze, Praha 2010