

OPTIMIZATION ALGORITHM SOMA APPLIED ON THE VIBRATION GENERATOR

Jiří Kurfürst

Doctoral Study Programme (1), FEEC BUT
E-mail: xkurfu02@stud.feec.vutbr.cz

Supervised by: Čestmír Ondrůšek

E-mail: ondrusek@feec.vutbr.cz

ABSTRACT

The article deals with the optimization algorithm SOMA - Self Organizing Migrating Algorithm. The problem is described on the vibration power generator. The vibration generator is mechatronic system based on the vibratory principle. Optimization is implemented on the real generator and the purpose of this optimization algorithm is to find the new optimal parameters such as the geometric dimension and the electrical parameters. These parameters separate problem to several parts. MATLAB-Simulink is used to solve dynamic behaviour of generator. Input parameters into SOMA: Acceleration is $0,2g$ [ms^{-2}] and frequency is 17 [Hz]. The SOMA consists of several strategies and in this paper the strategy All to One was used.

1. INTRODUCTION

In present time optimizing algorithms are very well applied on the chosen problems in all fields of engineering. Most of these activities use deterministic methods where they often converge to one of the local minima or fail to solve problem.

This work deals with the complex optimal design of the vibration - generator with required power 20mW. A generated power depends on ambient vibrations and of construction electrical and mechanical part. This energy source can be use for feeding the wireless sensors situated on the moving machines or remote application which need own sources [6], [7] and [8]. The optimization method SOMA – Self Organizing Migration is used to design new parameters. This algorithm is a new optimization technique in engineering [3], [4] and its topology class SOMA belongs to stochastic algorithms for global optimization.

2. GENERAL INFORMATION

Entire design process of the vibration power generator (Fig. 1 a) from the input values to the resulting device is very complicated. Therefore, the proposed optimization methods are based on the Artificial Intelligence. Those are very effective. This project is focused on the optimization method SOMA – AllToOne. The Optimization algorithm SOMA works with the individual optimization parameters of the mechanical and of the electromagnetic part. By these parameters the mechatronic system is optimized the SOMA.

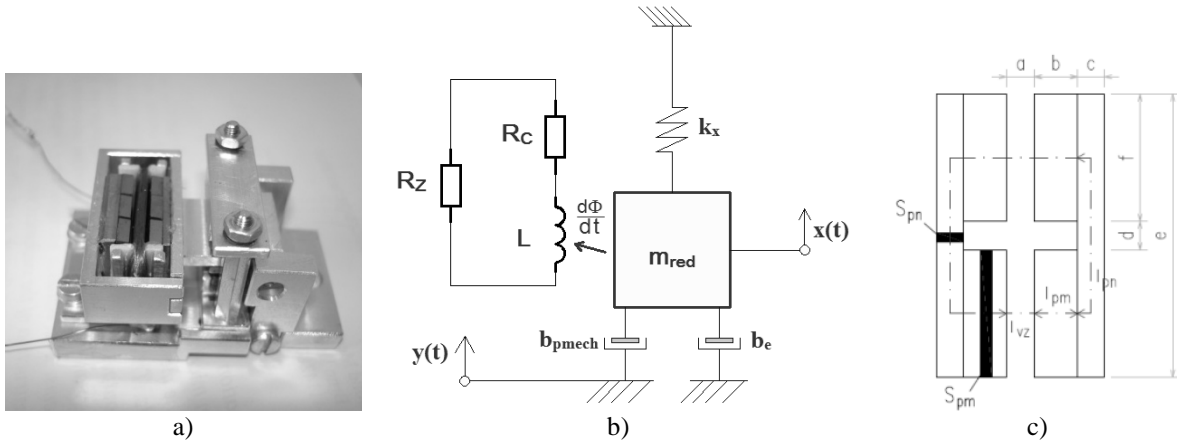


Fig. 1: Vibration power generator [7], b) Model of generator, c) Magnetic circuit [8]

The model of electromagnetic vibration power generator consists of:

- **Resonance Mechanism** is tuned up to the frequency 17Hz of excited vibration with acceleration 0,2g and it provides a relative movement of magnetic circuit.
- **Magnetic Circuit** provides a magnetic flux through the coil and NdFeB magnet was used.
- **Coil** is placed inside the moving magnetic circuit and it is fixed to the frame of the generator. Material of coils is Cu.
- **Electrical Load.** For the optimization load with 3500Ω was used.

3. MODEL OF VIBRATION MICROGENERATOR

Mechatronic system is described by the following mechanical and electrical equations

$$\ddot{x}(t) + 2\Omega b_m \dot{x}(t) + \Omega^2 x(t) = Y_{\max} \omega^2 \sin(\omega t) \quad (1)$$

The equation of mechanical part (1) describes the displacement of oscillation x of a mass around the fixed coil. b_m is overall damping consist from mechanical damping and electric damping ratio. The quality factor of the oscillating system with operating frequency Ω is described by the mechanical damping ratio b_{pm} . The system is excited by the acceleration $Y_{\max} \omega^2$.

The electrical equation follows in the Faraday's law and the second Kirchhoff's law. If the electrical load is connected a current will flow through the coil and the generator load. The electrical system induces the electro-magnetic damping ratio b_{pe} (Fig. 1. b) where the current flow through the coil provides feedback to the mechanical system in equation (1).

Magnetic flux in air gap is solved using Hopkinson's law. The operating point of permanent magnet is determined by the geometric feature of the magnetic circuit and the feature of the using magnets, (Fig. 1 c).

$$B = \frac{1,3074}{1 + 1,3687 \cdot 10^{-6} \left(\frac{1}{2\mu_0} \cdot \frac{a}{b} + \frac{1}{2\mu_0 \mu_{pm}} \cdot \frac{f(d+f+c)}{bc} \right)} \quad (3)$$

The dynamic system of the vibration power generator is solved by the programme Simulink, [8].

4. SELF ORGANIZING MIGRATING ALGORITHM

The SOMA optimization algorithm is based on the geometric principle. The method was established in 1999, developed by author Ivan Zelinka at the University of Tomas Bata, Zlín. The SOMA is one of the evolutionary algorithm works with a population of individuals where the environment (space) co-operatively scans (migration).

On the base of a theoretical description of SOMA [9] and free source codes on website, an optimization tool for the vibration power generator construction was created. A graphic interface of the SOMA optimization tool was built under thesis [8]. The optimization tool is performed by the following three problems.

- Optimization of generator with known connected load resistance.

This optimization is basically for first run of the optimization process. The programmer doesn't know what the volume of the generator is or what voltage will be generated.

- The generator optimization of nominal volume.
- The generator optimization to minimal volume and maximal power – will be described in this paper (results, etc.).

Different cost functions are developed for each optimization problem for the successful searching of a global extreme. The presented results correspond with the third optimization problems - generator with the minimal volume and the maximal output power. The cost function minimize overall of the generator volume with maximal output power and required output voltage (4 volts and higher). All cost factors have approximately equivalent effect in the cost function. A calculated value of the cost function depends on a choice of individual function coefficients.

5. THE RESULTS AND THE EVALUATION OF PROCESS OPTIMIZATION

The whole process of the calculating was started several times over for making the evaluation of the speed of convergence and the correctness of optimizing result. Each run was carried out with other initial conditions. Table I. shows the relative power change with a five-run of the optimization process. These values of the error performance are not very different from each other. The largest and the lowest values differ by a maximum of 2.48%

SIMULATION 0,2g	P_{el}	V_z	V
	[mW]	[V]	[V]
	20,1	8,39	33,34
Check values	P_{el} [%]	U_z [%]	V [%]
1	2,4876	1,1251	3,3563
2	1,4925	0,8880	1,7966
4	0,4975	0,3218	1,1698
5	0,4975	0,2503	0,2999
Max. error	2,4876	1,1251	3,3563

TABLE I. Relative errors optimization process

During testing, there was found that in all three optimizations the rate of convergence to the correct outcome affects the evaluation function. Weight coefficients influence substantially the convergence of solution. Equation no. (4) shows the given way of the preparation of objective function.

$$CostVal = \frac{EDIT_1}{U_{zMax}} + \frac{EDIT_2}{P_{zMax}} + EDIT_3 \cdot V \quad (4)$$

In an equation (4) was the edit button named EDIT used as the weighting function of the argument objective function. Using these buttons the weight of argument was adjusted, exactly by the element, which will dominate during the appraisal of optimization round.

The generator parameters for operating conditions (frequency 17 Hz, level of vibration 0.2 g, b_{pm} 0.025 and load resistance 3500Ω) were optimized. The graphic output with several representative parameters from this optimization study is shown in Fig. 2.

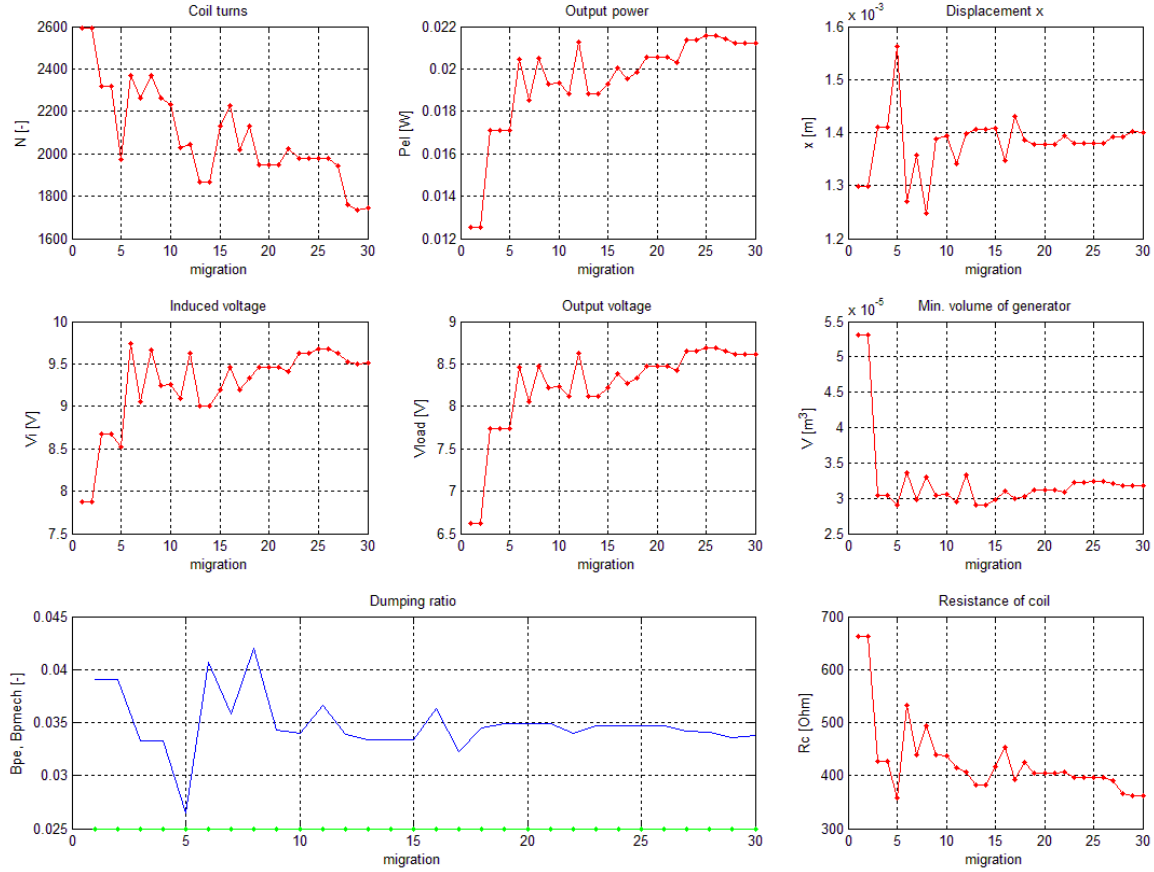


Fig. 2: Graphical outputs from optimization

There is a comparison of the original generator with optimized (new) generator in Table 2. The optimization process was successful and the new generator design has smaller volume at the same output power.

Values	Unit	Parameters	
		Original generator	Optimized generator
Volume	cm ³	80	34
Coil	turns	2000	1790
Resistance of coil	Ω	1600	350
Operating frequency	Hz	17	17
Output Power 0,2 G	mW	20	20,1

TABLE 2: Performance data of generator

CONCLUSION

The optimization problem of vibration power generator from input values is too difficult. The SOMA appears to be suitable optimization tool for such complex mechatronic systems. This study shows that optimized generator, which is placed in environment with mentioned conditions, can harvest output power 20.1 mW inside overall volume 38 ccm. The advantage of simulation modeling of vibration power generator is exciting by the real vibration data and monitoring of assumed output voltage and power during excited time.

ACKNOWLEDGEMENT

The work in this paper is supported by the project FEKT – S – 10 – 10, GA 102/09/1875.

REFERENCES

- [1] DOS SANTOS COELHO, L. Self-Organizing Migrating Strategies Applied to Reliability-Redundancy Optimization of Systems. *Reliability, IEEE Transactions on* [online]. 2009, vol. 58, is. 3 [cit. 2010-01-15], s. 501-510. ISSN 0018-9529.
- [2] DOS SANTOS COELHO, L. Self-organizing migration algorithm applied to machining allocation of clutch assembly. *Mathematics and Computers in Simulation* [online]. 2009, vol. 80, is. 2 [cit. 2010-01-25], s. 427-435. doi: 10.1016/j.matcom.2009.08.003
- [3] ONWUBOLU, Godfrey C., BABU, B. V. *New Optimization Techniques in Engineering*. Hardcover. 1st edition. [s. l.] : [s.n.], 2004. 712 s. ISBN 978-3-540-20167-0.
- [4] I. Zelinka "SOMA - Self-Organizing Migrating Algorithm," In: B.V. Babu, G. Onwubolu Eds., *New optimization techniques in engineering*, Springer-Verlag, chapter 7, 2004.
- [5] VARACHA, Pavel, ZELINKA, Ivan. Analytic Programming Powered by Distributed Self - Organizin Migrating Algorithm Application . *7th Computer Information Systems and Industrial Management Application* [online]. 2008, no. 978-0-7695-3184-7/08 [cit. 2010-01-21], s. 1-2.
- [6] HADAŠ ZDENĚK, SINGULE VLADISLAV, ONDRŮŠEK ČESTMÍR,,: *Overall tuning up of vibration generator and choice of energy transducer construction*, In *Advanced Engineering Design 2006*. Prague: **Orgis**, s.r.o, 2006. s. 1-5.
- [7] HADAŠ, Z.; ONDRŮŠEK, Č.; KURFÜRST, J. Optimization of Vibration Power Generator Parameters Using Self- Organizing Migrating Algorithm. In *Recent Advancecs in Mechatronics 2008- 2009*. 1. Berlin: **Springer-** Verlag Berlin Heidelberg, 2009. s. 245-250. ISBN: 978-3-642-05021- 3.
- [8] KURFÜRST, Jiří. *Optimization of vibration micro-generator*. Brno, 2009. 67 s. Diploma thesis. Brno University of Technology, Faculty of Electrical Engineering and Communication, 2009. 67 p. Supervisor Prof. C. Ondrusek.
- [9] SOMA, I. Zelinka, Faculty of Technology, Tomas Bata University, Czech Republic. [online]. [cit. 01.10.2009]. URL: <<http://www.ft.utb.cz/people/zelinka/soma/>>