MODELling THE CONTROL OF THE MOTOR FOR A EXPERIMENT TO MEASURE THE GRAVITY SPEED

C. A. Fabricio Junior, C Frajuca, D. M. da Silva, F S Bortoli, E. Sanchez
1 Instituto Federal de Educacao, Ciencias e Tecnologia de Sao Paulo
Rua Pedro Vicente, 625, Caninde – Sao Paulo – SP – Brazil BR
CEP: 01109-010 www.ifsp.edu.br
2 Instituto de Pesquisas Tecnologicas do Estado de Sao Paulo
Avenida Professor Almeida Prado, 532 - Butanta – Sao Paulo – SP – Brazil BR
CEP: 05508-901 www.ipt.br
3 Faculdade de Tecnologia de Sao Paulo
Avenida Tiradentes, 615 – Bom Retiro – Sao Paulo – SP – Brazil BR
CEP: 01124-060 www.fatecsp.br
E-mail: frajuca@gmail.com

Abstract: Brushless DC motors (BLDCM) are recognized for their high efficiency and low maintenance cost and are continuously subject to change in applications without motion control. The BLDCM can be used as an option to traditional switched reluctance motors. For the control of the speed of permanent magnet motors the more common is an integral proportional control (PI). The PI drivers are widely used because of a simple, easy-to-implement control structure, but they are presented as control complexities, such as non-linearity, parametric load perturbations and protection. The use of this method of pulse control (PWM) using a SIMULINK / MATLAB simulation to obtain the values necessary to control the speed of the brushless motor used in the gravitational wave calibrator prototype. SIMULINK / MATLAB is used to become a reliable and flexible simulation. The command will be used for precision accuracy of a ten thousand version of the calibrator.

1. Introduction
The Graviton Group is a research Brazilian group dedicated to the study of Gravitational Waves. The detection of gravitational waves came after a long road of experiments planned in 2010 [1], in 2016 finally the detection was made [2,3]. Gravitational waves got a very strong evidence with the PSR B1913+16 (also known as PSR J1915+1606, PSR 1913+16, and the Hulse–Taylor binary after its discoverers) is a pulsar (a radiating neutron star) which together with another neutron star thus forming a binary star system. PSR 1913+16 was the first binary pulsar to be discovered and its orbital period is decreasing with time due the emission of gravitational waves [4]. The first attempts to gravitational wave detection starts in the early sixties [5] with the resonant mass gravitational wave detection [6,7,8,9].

The Brazilian efforts towards the detection of gravitational waves are centered on the Schenberg detector. In the Schenberg detector six sensors are connected to the surface of the sphere, arranged according to the distribution of Merkowitz and Johnson [10]. These transducers are located as if they were in the center of 6 pentagons connected in a surface corresponding to half dodecahedron. Each transducer amplifies the motion occurring on the region of the sphere in which it is connected. The already amplified movement excites the membrane of one resonant cavity. In the resonant cavity microwaves are pumped, which generate the electronic signal that will return taking all the
information of the OG's. Intensity and direction of the OGs can be obtained from the analysis of the output signal of these 6 transducers [11,12,13].

To reach the resonant cavities, first the microwaves are conducted from the outside of the dewar (thermo flask where every antenna system is contained) by cabling to microstrip antennas. These antennas, located in front of the parametric transducers, conduct the microwaves into the resonant cavity and another set of antennas pick up the returned signal. The Brazilian efforts on the field can be summarized in [14-31].

1.1 Objective
The objective of this work is the study of an experiment to enable the integral proportional control (PI) of a brushless motor (or brushless motor) using the prototype of the gravimetric calibrator. With the feasibility of the prototype, a periodic gravitational signal can be generated that will be used for calibration of the Schenberg detector.

Brushless motors are widely used in a wide range of applications, ranging from aerospace to medical. The reasons are many for this choice because these motors have high efficiency, wide variety of speed, high torque in relation to their size, there are no sparks during their operation, there is no switching noise, no brushes that need to be replaced, there is a low maintenance cost and its size is smaller. The PI control is widely used for speed control associated with the pulse modulation (PWM) technique because it is easy to implement.

2 Gravitational signal generation
The study was initiated by the system proposed by Frajuca and Ruiz [32] where we have the representation of two bodies of mass 'M' rotating in a specific radius 'a' around an axis displaced in a distance 'r' [21]. This system as we see in Figure 1 has become the basis for the evolution of the prototype. From this study was designed and manufactured the prototype of calibration of gravimeter in small scale.

![Figure 1: Simplified model of the detector and the emitter of periodic tidal gravitational signals. Source - Frajuca and Ruiz [32]](image)

2. Gravity calibration prototype
The gravimetric calibration prototype is an equipment that fits into the well-known class of engineering problems called "High Speed Rotary Machines" or MAVs. The guidelines for the device have already been previously defined [33].

Another work already developed [34] refers to the construction of a small scale device, which can be seen in Figure 2 using better materials and associated to solve the problems of balancing and alignment, but the control circuit used was open loop.
3. The PI controller
In speed control of an industrial motor the PI controller is used to solve noise problems and increase the stability of the system. With a PI controller it is possible to improve the speed response because we have the proportional and integral terms acting on the controller, the velocity is then controlled by the appropriate excitation of the stator coils which can be effected through the PWM technique and with the knowledge of the position through hall sensors. Below we show the proposition of a model to carry out the control in Figure 3.

4. The PWM
A position feedback loop, for servo applications, is used for feedback. Knowing that the position feedback can be obtained through data derived from the position and a separate speed transducer can be eliminated for the speed control circuit. The position of the rotor is known through hall sensors and the BLDC motor is driven through the voltage pulses and the position of the rotor [35]. We can control the motor speed by varying its voltage across the motor. The motor voltage variation can be obtained by varying the duty cycle of the PWM signal.
5. Conclusion
Evaluating the above conditions it is possible to say that the answers found through the data that will be extracted from the modeling and the simulation will be the best ones to implement the speed control using the PWM technique and to reduce the time with physical tests. The disturbances that the model may not contemplate will not affect the results significantly.

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References:
[1] The Gravitational Waves International Committee Roadmap (GWIC). A global pan. June 2010.
Glaskow: Univerty of Glasglow - Department of Physics and Astronomy - Kelvin Building (G12 8QG), 117p.
[2] Taylor J H, Hulse R A, Fowler L A, Gullahorn GE, Rankin J M 1976 Astrophysical Journal 206 L53
[3] Weber J 1960 Physical Review 117 306
[4] Thorne K S 1987 “300 years of gravitation”. Cambridge: Cambridge University Press: 1987, p.330.
[5] Blair D G “The detection of Gravitational Waves.” 1991 Cambridge: Cambridge University Press
[6] Richard J P 1984 Physical Review Letters 167 165
[7] Aguiar O D et al. 2006 Journal Class. Quantum Grav. 23, 239
[8] Frajucia C et al. 2004 Class. Quantum Grav. 21 1107
[9] Velloso W F, Aguiar OD and Magalhaes NS Proc. First International Workshop for an
Omnidirectional Gravitational Radiation Observatory 1997 Singapore:World Scientific
[10] Merkowitz S M and Johnson W W 1993 Phys. Rev. Lett. 70, 2367
[11] Locke C R, Tobar M E and Ivanov E N 2000 Rev. Sci. Instrum. 71, 2737
[12] Ribeiro K L et al. 2004 Class. Quantum Grav. 21, 1225
[13] Andrade L A et al. 2004 Class. Quantum Grav. 21, 1215
[14] Aguiar O D et al. 2012 Journal of Physics: Conference Series 363, 012003
[15] Aguiar O D et. al. 2005 Class. Quantum Grav. 22, 209
[16] Frajucia et al 2002 Class. Quantum Grav. 19 1961
[17] Magalhaes N S et al. 1997 Astrophysical Journal 475, 462
[18] Magalhaes N S et al. 1995 MNRAS 274, 670
[19] Frajucia C, Bortoli F S, Magalhaes N S 2005 Brazilian Journal of Physics 35 1201
[20] Frajucia C, Bortoli F S, Magalhaes N S 2006 Journal of Physics: Conference Series 32 319
[21] Aguiar O D et al. 2004 Class. Quantum Grav. 21 459
[22] Frajucia C, Magalhaes N S, Horiguti A M 2008 Journal of Physics: Conference Series 122 012029
[23] Bortoli F S et al. 2010 Journal of Physics: Conference Series 228 012011.
[24] Magalhaes N S et al 1997 Gen. Relat. Grav. 29 1511
[25] Aguiar O D et al 2002 Brazilian Journal of Physics 32 866
[26] Bortoli F S et al 2019 Brazilian Journal of Physic 49 133
[27] Frajucia C, Bortoli F S, Magalhaes N S, Horiguti A M 2008 Journal of Physics: Conference Series 122 012029
[28] Frajucia C, Bortoli F S 2006 Journal of Physics: Conference Series 32 315
[29] Bortoli F S et al. 2016 Brazilian Journal of Physic 46 308
[31] Frajucia C et al. 2018 Journal of the Brazilian Society of Mechanical Sciences and Engineering 40 319
[32] Ruiz W 2014 2015 Experimento para medir a velocidade da interação gravitacional utilizando um
motor de relutância variável
[33] Fernandes Junior 2015 Diretrizes para o projeto do calibrator do detector Mario Schenberg
[34] Silva Neto, S 2018 Protótipo de Dispositivo para Calibração de Gravímetros - Modular (PDCG-M)
[35] vinod Kr Singh Patel, A.K.Pandey 2013 International Journal of Engineering Research and Applications (IJERA) 3(3) 612-620