

## SOFTWARE IMPLEMENTATION OF A MODERN VOLTAGE CONTROLLER

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**Abstract** - This paper presents a real-time software implementation of a robust voltage controller developed for multimachine power system. The software implementation is realized in LabVIEW and the hardware target is a PXI system with analog inputs, analog outputs connected to a power amplifier.

### 1. Introduction

In [1] was developed a robust voltage controller for naval power system. This controller improves the quality of voltage regulation onboard ships, addressing the problem of ships power system quality. The continuous model of the robust controller is put in a discrete form and a software implementation in LabVIEW Real-Time is realized. A real-time hardware is composed from a PXI chassis from National Instruments with DAQ cards. Also a power amplifier is design for connection with the excitation system of the generator.

### 2. Voltage controller model

The controller was developed through H<sub>∞</sub> techniques from the naval power system model developed in [1].

As stated in [1], the equations that describe the bus bar voltages are:

$$\dot{u}_d = \alpha u_d + \beta u_q + \eta_1 e_f \quad (1)$$

$$\dot{u}_q = \sigma u_d + \gamma u_q + \eta_2 e_f \quad (2)$$

where the coefficients are functions that depends of generators parameters and system operating point.

With the variables defined as:

$$z_1 = \int (u_d^2 + u_q^2 - 1) dt \quad (3)$$

$$z_2 = u_d^2 + u_q^2 - 1 \quad (4)$$

where  $u_d$  and  $u_q$  are bus bar voltages on  $dq$  axes, the system is summarized as:

$$\dot{z}_1 = z_2 \quad (5)$$

$$\dot{z}_2 = v_1 + \Phi(t)\theta(t) \quad (6)$$

where:

$v_1$  - a new variable which will control the system.

$$\Phi(t) = \begin{bmatrix} 2u_d^2 & 2u_d u_q & 2u_d u_q & 2u_q^2 & 2u_d e_f & 2u_q e_f \end{bmatrix}$$

$$\theta(t) = \begin{bmatrix} \alpha - \alpha_n \\ \beta - \beta_n \\ \sigma - \sigma_n \\ \gamma - \gamma_n \\ \eta_1 - \eta_{1n} \\ \eta_2 - \eta_{2n} \end{bmatrix}, \text{ vector of variation of the functions from their nominal values.}$$

The excitation voltage is:

$$e_f = \frac{v_1 - f(u_d, u_q)}{g(u_d, u_q)} \quad (7)$$

Where the  $f$  and  $g$  functions are defined in [1] and depend on the generators characteristics and system operating point.

A new control variable is chosen as:

$$v_2 = v_1 - z_1 \quad (8)$$

With this new variable the system becomes:

$$\dot{z}_1 = z_2 \quad (9)$$

$$\dot{z}_2 = z_1 + v_2 + \Phi(t)\theta(t) \quad (10)$$

Choosing the error weight as:

$$W_{e2} = \frac{0.01(s+10)}{s+10^{-9}} \quad (11)$$

perturbation weight:

$$W_p = \frac{1}{\frac{s}{50 \cdot 2 \cdot \pi} + 1} \quad (12)$$

and the control effort weight:

$$W_{act} = \frac{0.05(s+10)}{s+500} \quad (13)$$

The equation of the robust voltage controller is:

$$\dot{x} = \begin{bmatrix} 0.0005 & 0.00123 & -31.58 & 0 & 0 \\ -5444 & -1103 & -1.697e4 & -1967 & -66.27 \\ 0.000158 & 38.9e-5 & -9.998 & 0 & 0 \\ -2.295e4 & -2806 & 0 & -1.023e4 & -355.7 \\ 0.007623 & -2.569e4 & -8.124e5 & 0 & -31.42 \end{bmatrix} x + \begin{bmatrix} 4103 \\ 2.204e6 \\ 1297 \\ 0 \\ 1.055e8 \end{bmatrix} u \quad (14)$$

$$y = [-132.5 \quad -13.8 \quad 0 \quad -47.88 \quad -1.75]x^T$$

where:

$u$ —input vector composed from perturbation and additional variables as defined in [1].

The control signal (excitation voltage) is:

$$e_f = \frac{v_1 - f(u_d, u_q)}{g(u_d, u_q)} = \frac{v_2 + \int z_2 - f(u_d, u_q)}{g(u_d, u_q)} \quad (15)$$

### 3. Software and hardware implementation

The software used was LabVIEW Real-Time. The application controls duty cycle of a PWM signal connected to a DC to DC buck converter. The converter feeds directly the field winding of the synchronous generator.

The application has a user interface and through an embedded web server the operator can change the parameters online and view the current status of the controller.

The main applications have a configuring front panel as in figure 1. The timing of the acquisition and software loop is based on the analog input clock. The acquisition of the bus bar voltage is made as hardware timed single point.

The transformation of the  $abc$  to  $dq$  coordinates are made with a subVI presented in figure 2. The robust controller is implemented as a subVI with inputs the  $v_d$  and  $v_q$  from the acquisition and the output is feed to the counter pin of the daq card.

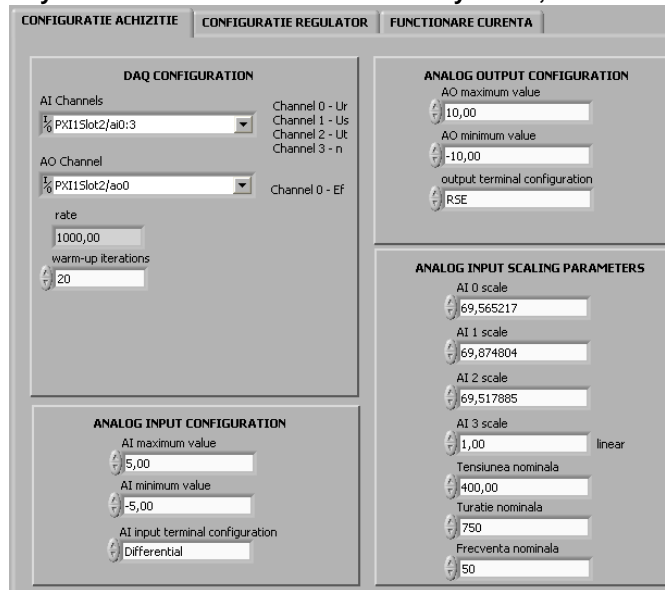


Figure 1. Front Panel of the main application

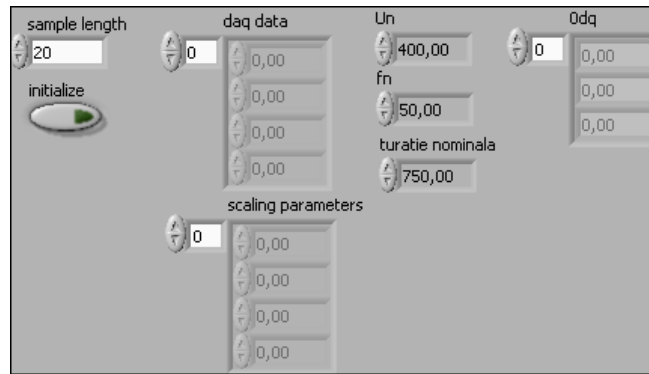


Figure 2. Front Panel of the rr\_abcTo0dq.vi

The front panel of the *regulatorHinf.vi* which implements the robust controller is presented in figure 3.

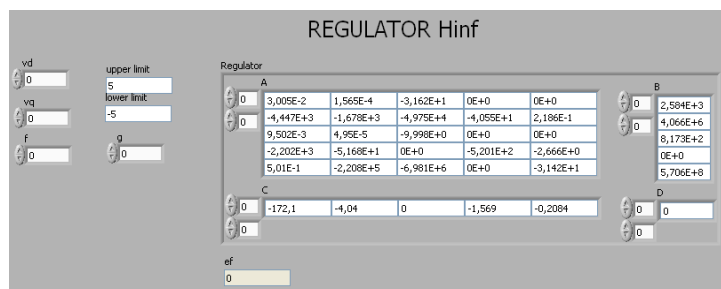


Figure 3 Front Panel of the regulatorHinf.vi.

The application presents the current status of the voltage controller through the “FUNCTIONARE CURENTA” window, presented in figure 4.

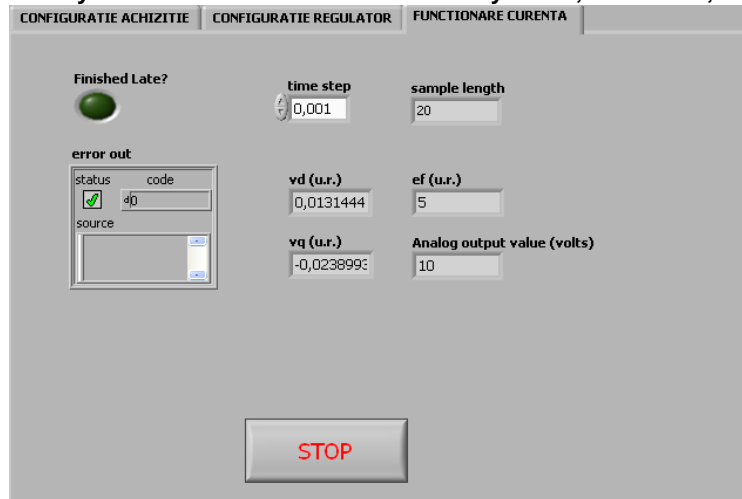


Figure 4 Controller operation point windows.

The hardware used is composed from PXI-8145RT real time controller, PXI-6251 data acquisition board and a DC to DC converter.

The real-time controller has the following characteristics:

- processor Intel Pentium 266MHz.
- operatingsystem PharLap RTOS
- memory RAM 128MB SDRAM
- watchdog timer
- loop rate  $1\mu\text{s}$  (hardware timing)
- system jitter < 4ns

The data acquisition card has 16 analog inputs with 16bit resolution with an input rate of 1MS/s, two analog output channels and 2 counters with 32 bit resolution.

The voltage transducers used are LV 25-P from LEM. The application has the analog input scaling parameters configuration window, in which the used can change the parameters accordingly with the new voltage transducers that can be used.

For the amplification a buck DC to DC converter. The converter schema is presented in figure 5.

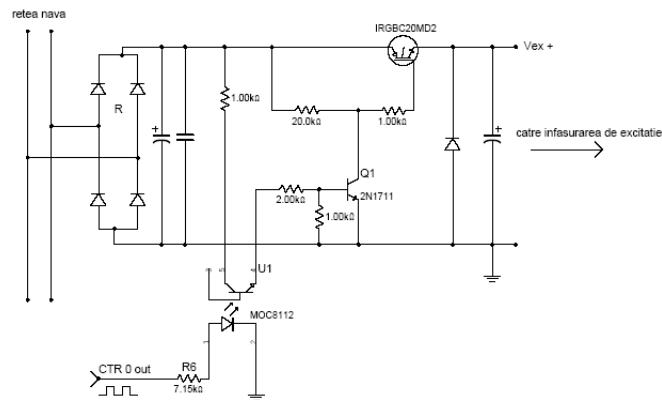


Figure 5. DC-DC buck converter

The converter is connected to the ship electrical system and is controlled by the counter output of the data acquisition card.

#### 4. Conclusions

This paper presents a software implementation in a real-time hardware of a robust voltage controller developed for multimachine power system. The software is fully configurable so future development or hardware components replacements (as voltage transducers) can be done with reconfiguration of application parameters.

#### References

- [1] Francis A. Okou, Ouassima Akhrif, Louis-A. Dessaint, Roger Champagne, „Application of a Multivariable Feedback Linearization Scheme for Rotor Angle Stability and Voltage Regulation of PowerSystems”, IEEE Transactions on Power Systems, vol.14, no.2, 1999.
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