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Design and Implementation of an IMC-1DOF Controller Applied to MPPT Photovoltaic Systems Using ZVS Full-Bridge DC-DC Converter

E. N. Chaves[1], G. P. Viajante[1], M. A.A. de Freitas[1], E. A. A. Coelho[2], M.E Oliveira[1], R. Nielson[3], L.G Wesz[1] and G. Moraes[2].

[1]Núcleo de Pesquisa em Sistemas de Energia – NuPSE
Federal Institute of Education, Science and Technology of Goiás - IFG
E-mail: ghuterp@gmail.com and mathheusbueno@gmail.com
[2]Universidade Federal de Uberlândia, Uberlândia – MG, Brasil
e-mail: ernane@ufu.br
[3]Enel Distribuição Goiás

1. Introduction

- This paper presents the design of an Internal Model Control – 1 Degree of Freedom (IMC-1DOF) controller applied to a Full-Bridge DC-DC converter that will be used in photovoltaic systems for Maximum Power Point Tracking (MPPT).
- It will be presented the mathematical modeling of this converter to control the input voltage aiming the application in MPPT and the design of the respective controller IMC-1DOF.
- The proposal testing and validation strategy was performed by comparison with a PI compensator.
- The performance of both controllers are evaluated and discussed.

2. Full-Bridge DC-DC Converter

Figure 1 shows the system structure involving the MPPT (Disturb and Observe - P&O) and the IMC controller, both in conjunction with the ZVS Full-Bridge DC-DC converter

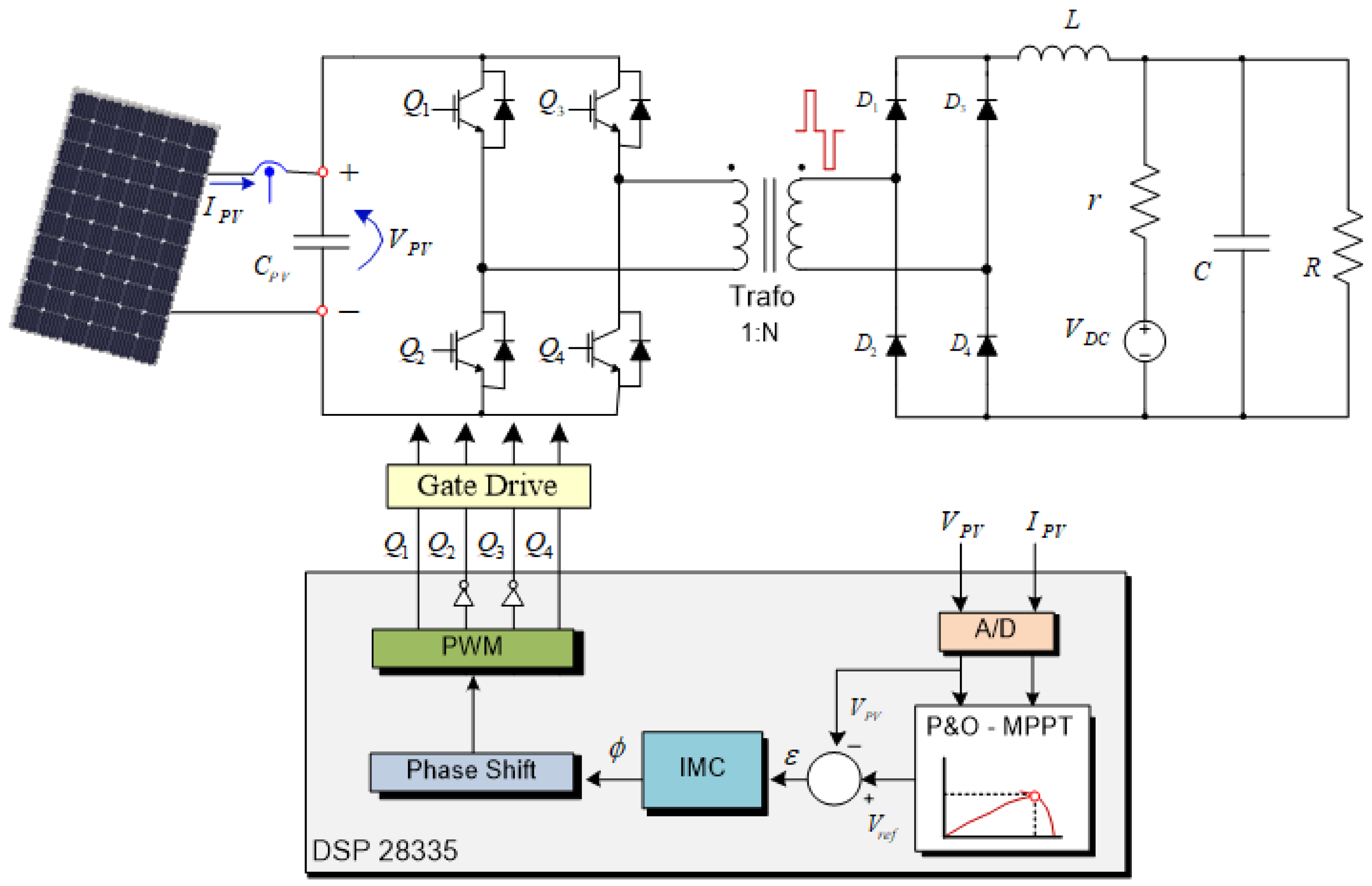

Fig.1. System structure involving MPPT, IMC controller and Full-Bridge DC-DC Converter

3. DC-DC Converter Modeling

- For the controller design, the modeling process of the ZVS Full-Bridge DC-DC converter was performed through **medium state spaces**

Two steps associated with the converter were considered.

- **During Step 1**, shown in Figure 2 (a), switches Q2, Q3, D1 and D4 remain closed for a time dTSW and Q1, Q4, D2 and D3 open.
- **In Step 2**, Figure 2 (b), switches D2 and D4 remain freewheeled to the inductor current (L) for a time equivalent to (1-d) TSW. In addition, switches Q1 and Q3 or Q2 and Q4 also remain closed on (1-d)

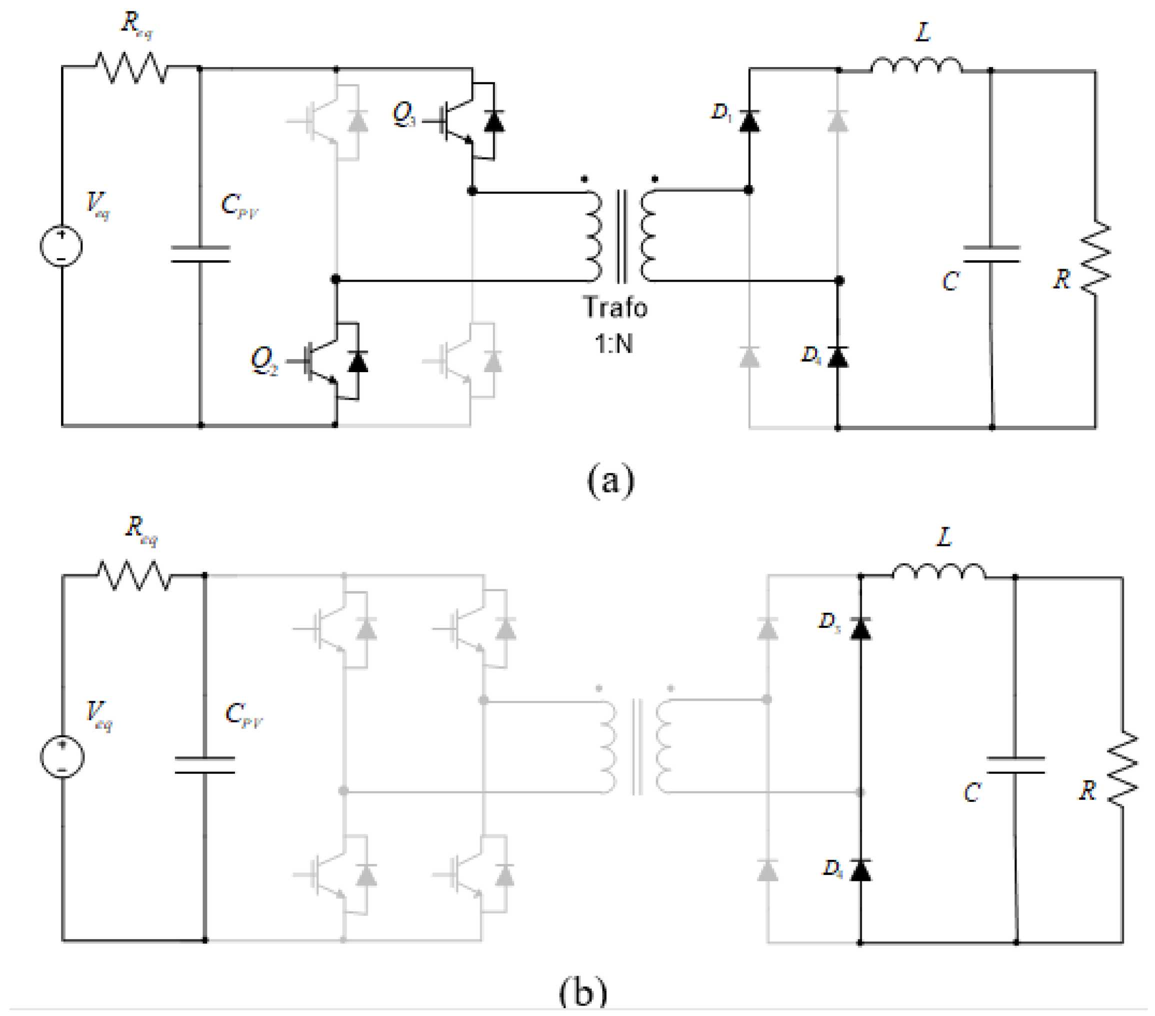

Fig. 2. DC-DC converter steps at both switching intervals..

$$\hat{G}_{v_{pv}/d} = \frac{N_2 R_{eq}(b_2 s^2 + b_1 s + b_0)}{a_3 s^3 + a_2 s^2 + a_1 s + a_0}$$ Transfer Function

4. PI compensator and IMC Controller Design

The **PI compensator** was designed with the aid of the Sisotool® tool from Matlab® software. Tuning was done using the Ziegler-Nichols method for unit step response. **The transfer function of this compensator** is:

$$G_{PI}(s) = 0{,}013278\frac{(s+1822)}{s}$$

IMC 1DOF controller can be designed as:

$$q(s) = \frac{D(s)}{N(s)\cdot(\varepsilon s+1)^r} \qquad \frac{1}{(\varepsilon s+1)^r}$$

where: *N(s)* is the numerator polynomial and
D(s) is the transfer function denominator polynomial
r is defined as the difference between the denominator order minus the numerator order of the transfer function.

5. PI Compensator Results

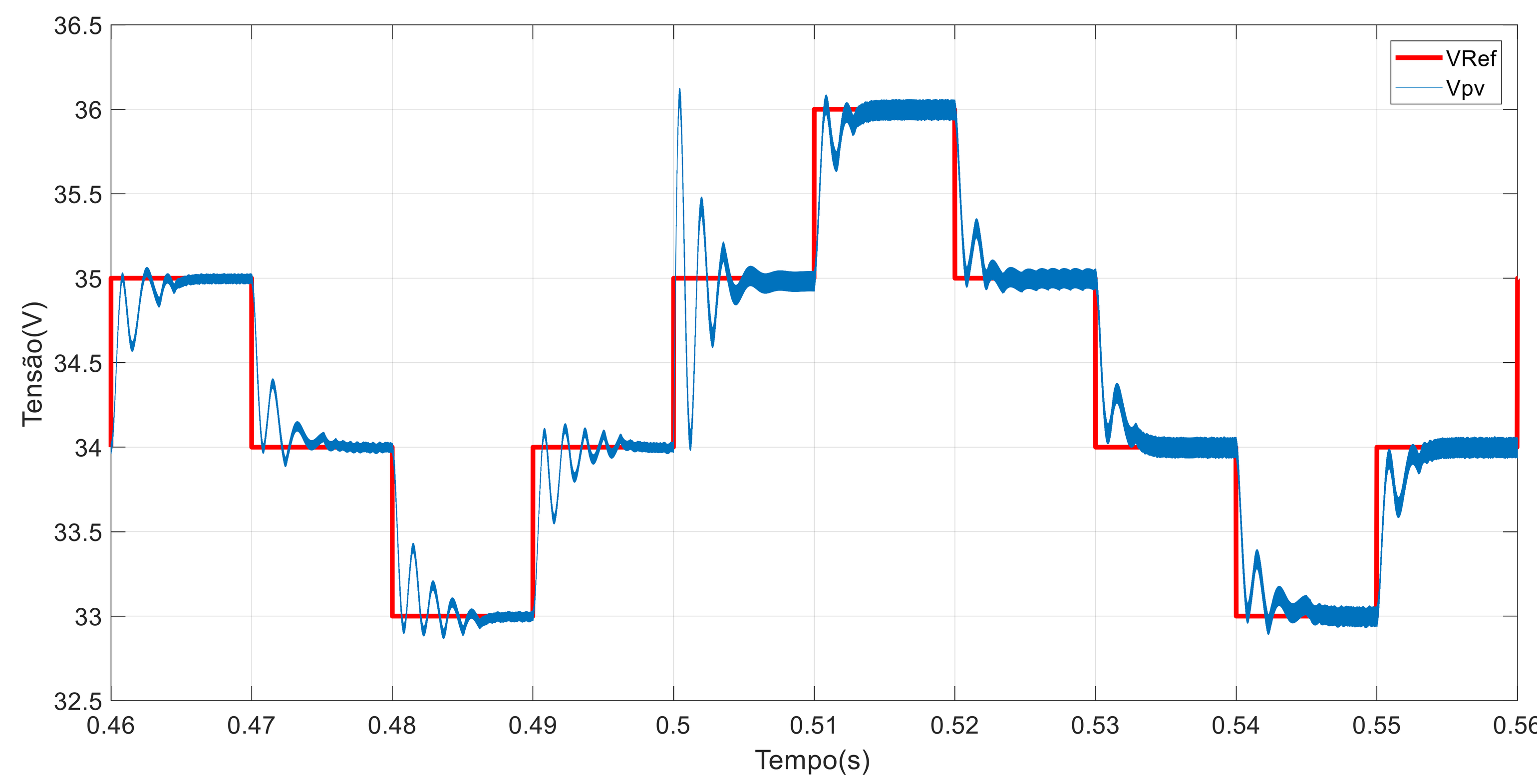

Fig 3 - Reference voltage (VRef), being disturbed by P&O, and the voltage at the terminals of the photovoltaic panel (VPV) - Action of the PI compensator.

6. IMC Controller Results

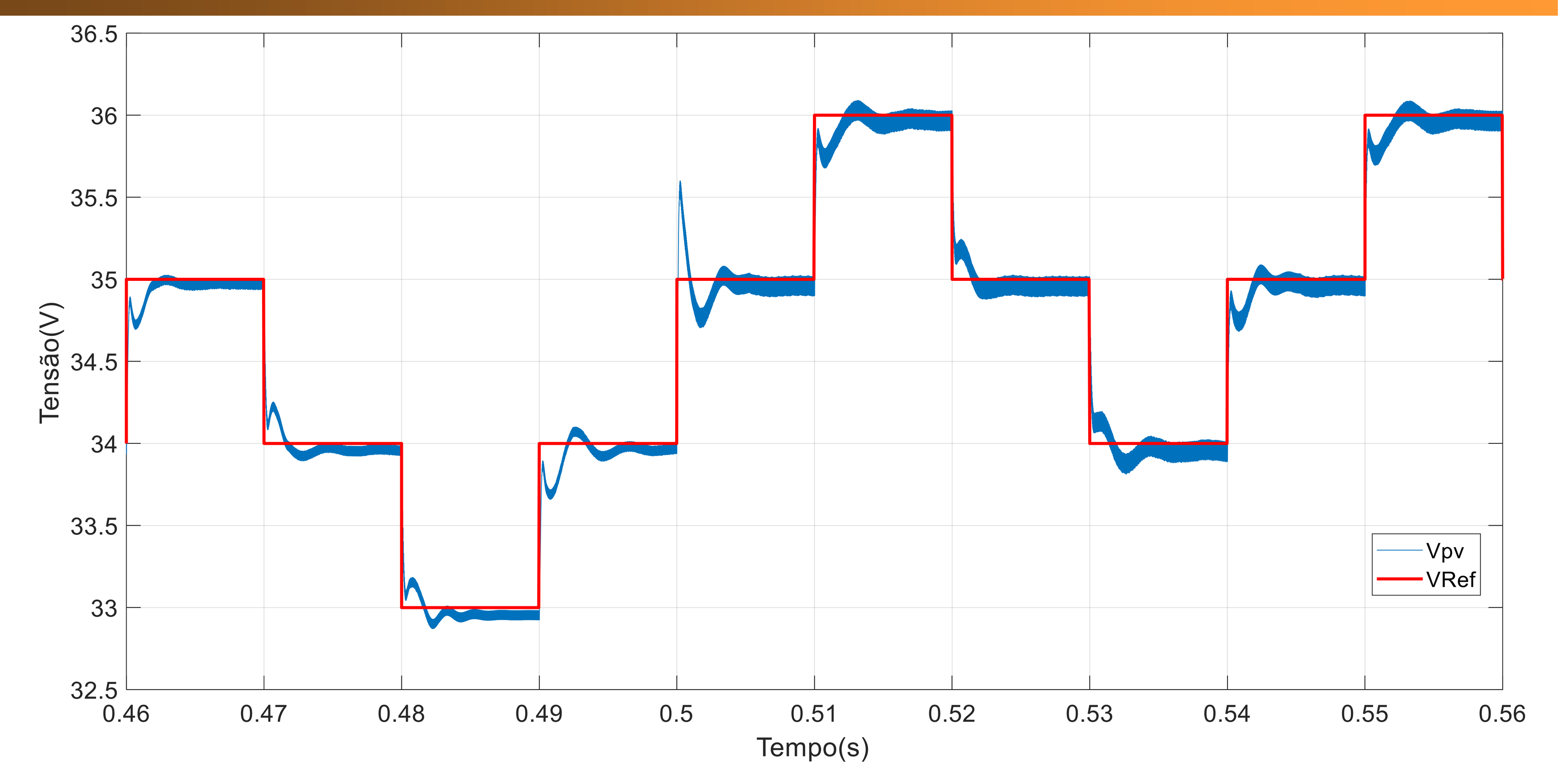

Fig 4 - Reference voltage (VRef), being disturbed by P&O, and the voltage at the terminals of the photovoltaic panel (VPV) - Action of the IMC Controller.

7. Conclusion

- PI compensator maintained the voltage response (*Vpv*) with fast stabilization around the reference and zero error when in steady state.
- It presented overshoot and oscillations much higher than IMC controller.
- PI compensator was a little more difficult to tune because it required a compromise relationship between speed of response and saturation in the control action.
- IMC proved to be easier to tune, since it is necessary to adjust a single parameter (ε) related to the system cutoff frequency and its closed-loop response speed.
- IMC controller maintained the voltage response (*Vpv*) with fast stabilization around the reference