J.C. **Antolín–Urbaneja**[*a], A. Cortés[a], M. Marcos[b], J. Lasa[a], P. Estensoro[a], I. Cabanes[b]
[a]TECNALIA Research & Innovation, Mikeletegi 7, 20009 Donostia-San Sebastián, Spain
[b]Automatic Control and Systems Engineering Department, School of Engineering, University of Basque Country, 48103 Alameda Urquijo, Bilbao, Spain

Assembled PTO based on an array of double-acting hydraulic cylinders for WECs: From Conceptual Design to an Adjusted Detailed Model

Introduction

All Wave Energy Converters (WECs) based on wave activated bodies comprises a Power Take-Off (PTO) system among other subsystems like the reaction mechanism, the supervisor of the system and the electrical generator[1]. Depending on the WEC technology, some different PTO approaches can be used[2]. One of the most applied PTO systems consists of high pressure hydraulic devices. These devices are able to apply high forces, to store large quantities of energy through accumulators and to provide smoother power output to the motor coupled to a generator. In these systems, the poor efficiency and the oil leakages contaminating the environment are considered main drawbacks. Despite of this, they are widely used in several promising WECs[2] with the aim of optimizing the harvested wave energy along the time. This work presents a patented[3] oil high pressure hydraulic PTO based on an array of four double-acting hydraulic cylinders independently controlled. This model has been designed from the concept at 1:4 scale and further developed to a complete adjusted model ready for investigating control strategies to optimize the extracted wave energy of specific WECs characterized by the application of an oscillating and low speed input in the input of this PTO.

From Conceptual Design to Adjusted Detailed PTO

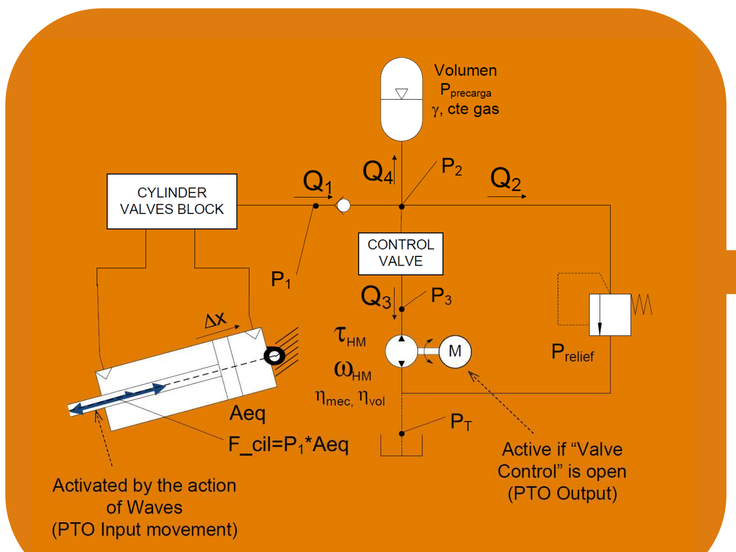


Figure 1. Simplified Hydraulic PTO Model[4]

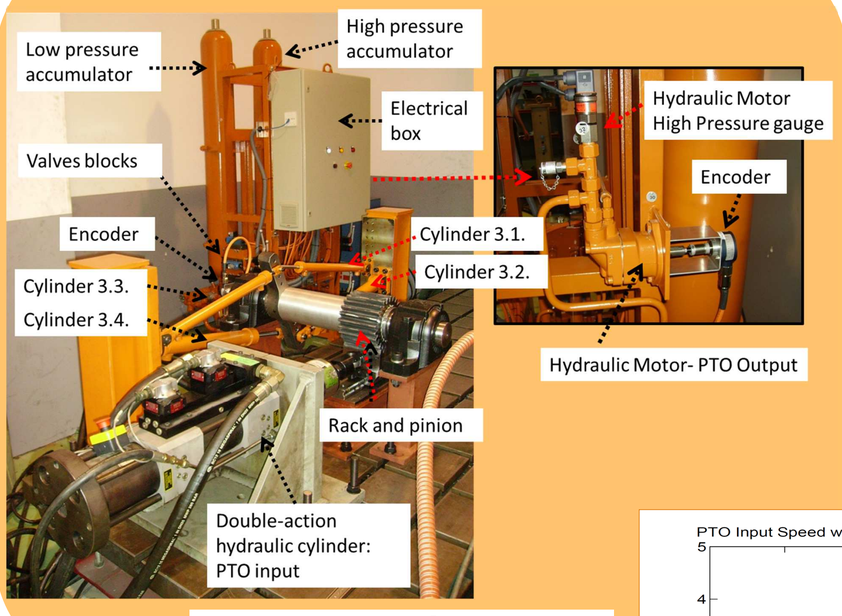
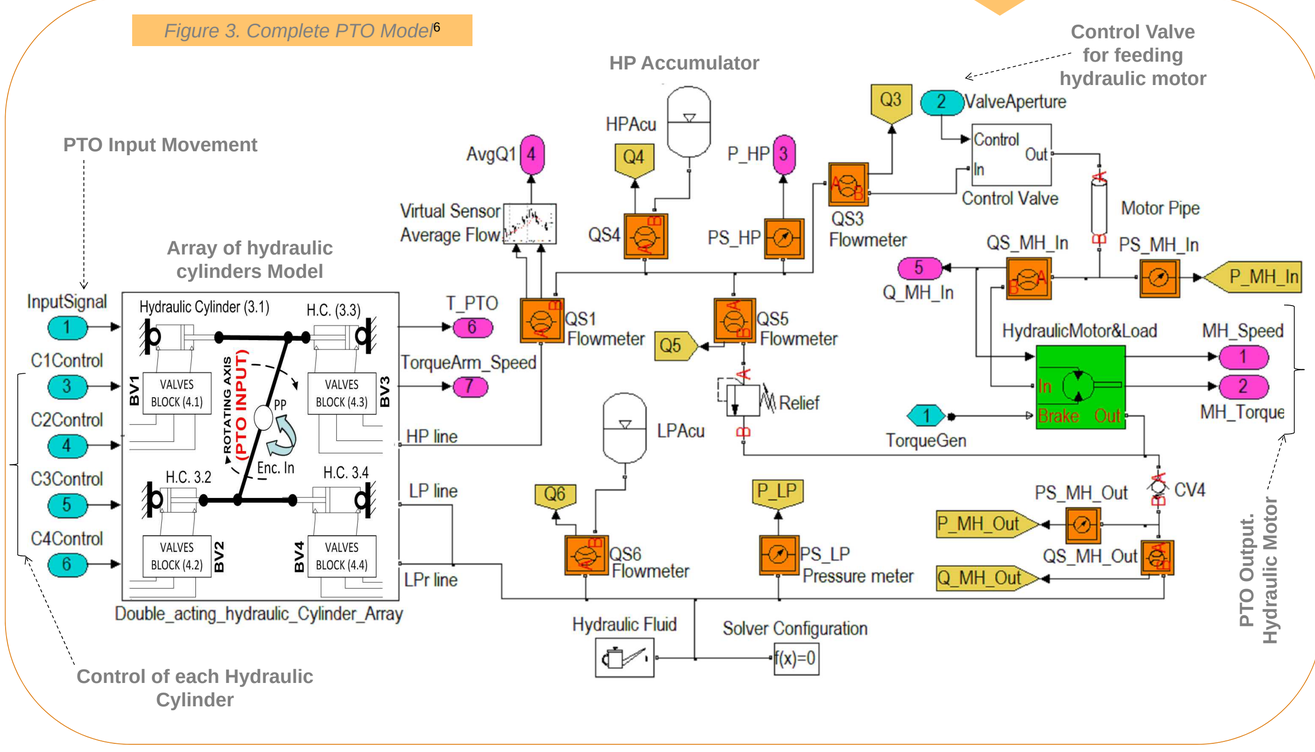


Figure 2. Assembled PTO[5] on the Test bench

The initial challenge to absorb an oscillating movement of ±30º at 5rad/s as a maximum angular speed absorbing up to 16000Nm from an specific WEC, led to the development of a simplified hydraulic model (Figure 1) before manufacturing the PTO to be verified in a Test Bench[4] (Figure 2). Combining experimental tests[5] under different conditions (regular waves) and the detailed PTO Model[6] (Figure 3) the model of the assembled PTO has been adjusted to obtain similar results in the PTO input (Figure 4) and PTO output (Figure 6) using Simulink® and the Toolbox of Simhydraulics®. Figure 5 shows some of the variable Coulomb type damping torque depending on geometrical parameters[3-5] and the combination of activated double-acting hydraulic cylinders.

Figure 3. Complete PTO Model[6]



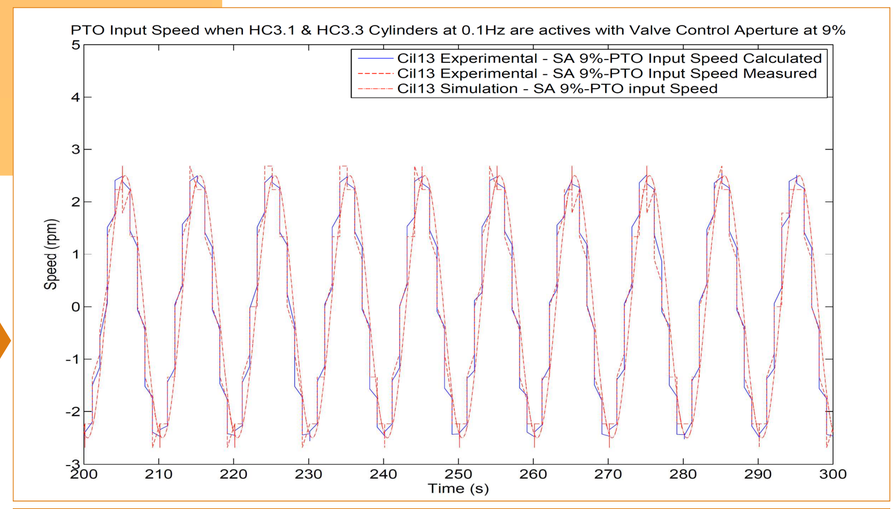


Figure 4. Comparison between simulated PTO input speed and Measured PTO input Speed[6]

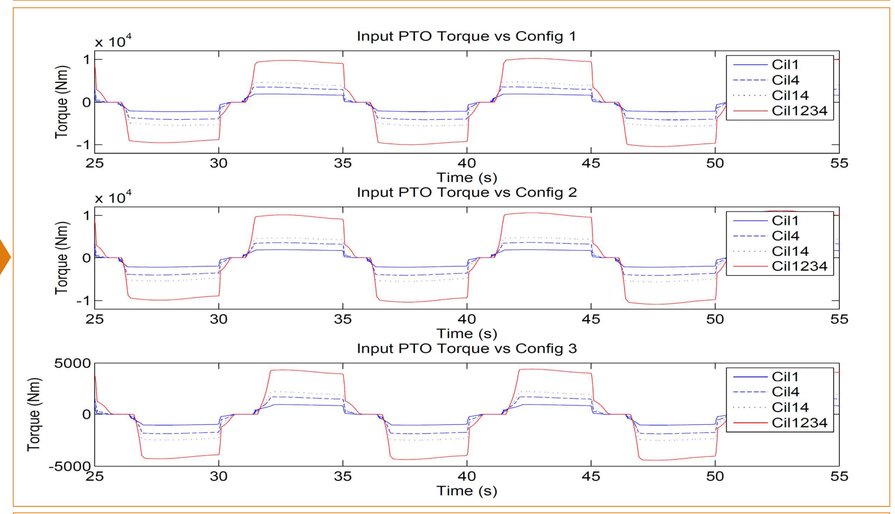


Figure 5. Coulomb damping Torque evolution at the PTO input. Comparison between different geometrical configurations using same activated hydraulic cylinders[6]

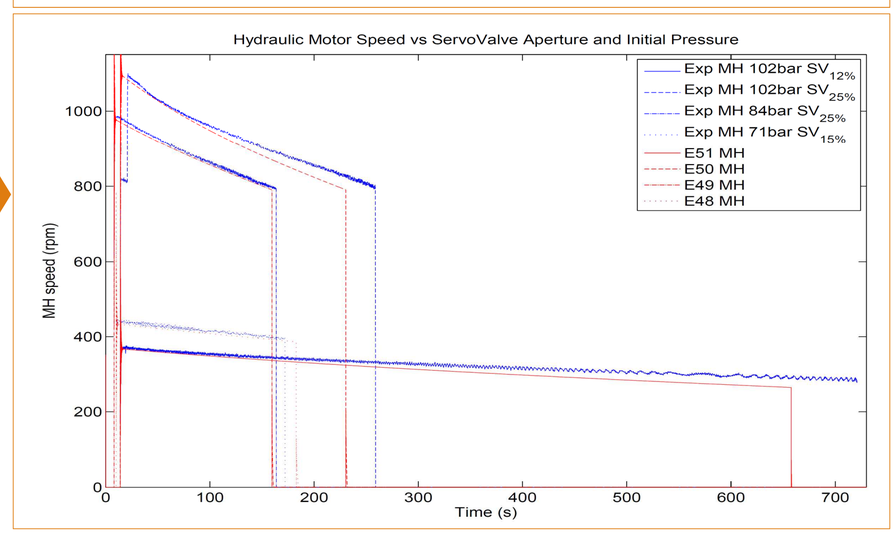


Figure 6. PTO Output. Comparison of the hydraulic motor speed (rpm) between simulated (red) and experimental (blue) tests[6]

Conclusions

- Patented PTO based on double-acting hydraulic cylinder array has been presented.
- This PTO is able to apply a variable Coulomb type damping torque through the activation of each hydraulic cylinder independently and through the modification of geometrical variables easily (now manually).
- Model of the PTO has been accurately tuned up through adjustment of model parameters compared to experimental tests. This will allow the study of control strategies to optimize the extracted wave energy of a specific WEC, like point-absorbers.
- Ongoing research is being carried out to characterize the PTO behaviour at higher pressure operation points (>100bar) and to implement it in conjunction with a specific point absorber

References

[1] S. H. Salter, J. R. M. Taylor, and N. J. Caldwell, "Power conversion mechanisms for wave energy," *Proc. Inst. Mech. Eng. Part M-Journal Eng. Marit. Environ.*, no. July, pp. 1–27, 2002
[2] A. F. D. O. Falcão, "Wave energy utilization: A review of the technologies," *Renew. Sustain. Energy Rev.*, vol. 14, no. 3, pp. 899–918, Apr. 2010.
[3] J. Lasa, J. C. Antolín, and P. Estensoro, "Power Take-Off device for Wave Energy transformation" EP2466118A1, 2012.
[4] J. Lasa, J. C. Antolin, C. Angulo, P. Estensoro, M. Santos, and P. Ricci, "Design, Construction and Testing of a Hydraulic Power Take-Off for Wave Energy Converters," *Energies*, vol. 5, no. 6, pp. 2030–2052, June 2012.
[5] J. C. Antolín-Urbaneja, J. Lasa, P. Estensoro, I. Cabanes, and M. Marcos, "Innovative Hydraulic Power Take-Off construction and Performance Tests for Wave Energy Conversion," *Appl. Mech. Mater.*, vol. 432, pp. 316–323, 2013.
[6] J. C. Antolín-Urbaneja, J. Lasa, P. Estensoro, I. Cabanes, and M. Marcos, "Modeling Innovative Power Take-Off based on double-acting hydraulic cyllinders array for Wave Energy Conversion," *Energies* vol. 8, no. 3, pp. 2230–2267, March 2015.

Contact info:
Juan Carlos Antolín Urbaneja
T +34 667 119 568
juancarlos.antolin@tecnalia.com

TECNALIA
Parque Tecnológico de Miramón
C/ Mikeletegi Pasealekua, 7
E-20009 DONOSTIA-SAN SEBASTIÁN
(Guipuzcoa) Spain
www.tecnalia.com

Sponsor IBERDROLA

Organizers BEC! Bilbao Exhibition Centre · SINAVAL · tecnalia · Eusko Jaurlaritza Gobierno Vasco · EVE Ente Vasco de la Energía

BILBAO MARINE ENERGY WEEK
22th April 2015 Bilbao-Spain