Simulación de una estación de carga de un EV-HEV para baterías multichemistry utilizando la Representación Energética Macroscópica (REM)

Simulation of an EV-HEV charging station for multichemistry batteries using Energetic Macroscopic Representation (REM)

C. Aparicio [1], L. Pérez [2], J. Solano [3]

[1] Universidad Industrial de Santander, Colombia Email: cristinaaparicio gutierrez@hotmail.com
[2] Universidad Industrial de Santander, Colombia. Email: lkperezospino@gmail.com
[3] Grupo de investigación GISEL, Universidad Industrial de Santander, Colombia. Email: javiere.solanom@gmail.com

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RESUMEN
La masificación del vehículo eléctrico (EV por sus siglas en inglés) y el vehículo híbrido eléctrico (HEV) requieren la implementación y optimización de las estaciones de carga de baterías adaptadas para cargar baterías eléctricas con diferentes tipos de químicas. Los algoritmos de carga se encargan de identificar la tecnología de la batería (Li-ion y NiMH) y realizar la recarga por periodos de tiempo más cortos para no afectar el ciclo de vida útil de la batería. Este documento utiliza el formalismo de Representación Energética Macroscópica (EMR) para modelar una estación de carga integrada con paneles eléctricos fotovoltaicos. Los resultados de la simulación muestran el proceso de carga para los vehículos eléctricos Nissan Leaf y Renault Twizy , además del vehículo híbrido Toyota Prius con tecnologías de Níquel, Li-ion y NiMH respectivamente.

PALABRAS CLAVE: Cargador multi-química o universal, Vehículo Eléctrico (EV), Vehículo Híbrido Eléctrico (HEV), algoritmo de carga, identificación de tipo de batería, Paneles Fotovoltaicos (PVP).

ABSTRACT
Massification of electric vehicles (EV) and hybrid electric vehicles (HEV) requires the implementation and optimization of battery charging stations adapted to charge multi-chemistry batteries. Charging algorithms must identify the battery technology (Li-Ion and NiMH) and perform a charge which minimize the charging time while maximize the batteries lifetime. In this paper, Energetic Macroscopic Representation (EMR) formalism is used to model a charging station with integration of photovoltaic generators. Simulation results illustrate the recharge of a Nissan Leaf and a Renault Twizy Li-Ion - EV and a Toyota Prius NiMH HEV charging.

KEY WORDS: Multi-chemistry batteries, Electric Vehicle (EV) and Hybrid Electric Vehicles (HEV), Charging algorithms, battery technology identification, Photovoltaic Panels (PVP).

1. INTRODUCTION

Electric vehicles (EV) and hybrid electric vehicles HEV industry is steadily growing worldwide. By 2017, Toyota has sold more than 6 million Prius the most successful HEV to date. In the EV side, with more than 250000 units the Nissan Leaf is the most sold EV in history. The principal challenge that face HEV and mainly EV industry is the capacity (autonomy) and the price of the batteries. In a market with emerging and mature battery technologies, each manufacturer has selected its own technology to electrify their vehicles.
From the user perspective, lack of charging infrastructure is one of the barriers to consider EV and HEV to replace conventional thermal vehicles. Charging stations should allow a fast charging of the batteries respecting the specific constraints of each battery technology. As to date, they are considered to electrify the most successful HEV and EV, this article focuses in algorithms to charge Nickel Metal Hydride (NiMH) and Lithium-ion (Li-Ion) technologies.

The article is organized as follows: Section 2 introduces charging algorithms for NiMH and Li-Ion batteries. Section 3 proposes a representation to organize the model of a charging station with integration of photovoltaic energy. Section 4 presents simulation results.

2. Li-Ion AND NiMH CHARGING ALGORITHMS

Li-Ion and NiMH are the most common chemistries used in EV and in HEV respectively. Each technology has its own regime of charge based on its inherent electrochemical characteristics. Different charge algorithms have been designed to reduce the charging without a compromise in the batteries life span.

2.1 Charging algorithms for NiMH batteries.

The selected algorithm to charge NiMH batteries is presented in [1]. It considers two operation modes: it starts with a constant injection of current (CC) followed by a trickle charge mode, which consists on an injection of current pulses. The condition to change to the trickle charge mode are the detection of an inflection point in the battery voltage, the apparition of a voltage drop a high increment of temperature or a limit time.

2.2 Charging algorithms for Li-Ion batteries.

The selected algorithm to charge Li-ion batteries is presented in [2]. It is performed in three steps: it starts with a CC charge followed by a constant voltage (CV) charge mode and finish with a trickle charge. The conditions to change between charge modes are the voltage drop, the detection of the inflection point and the exceeding of the limit temperature or time.

2.3 Identification algorithms.

Universal chargers must identify the battery technology before starting the charging process. Identification algorithms presented in [3] are implemented to determine the battery connected to the charger. The technique to identify consist in the measurement of hysteresis that comprises the measurement of the Open Circuit Voltage (OCV) after a discharge and a charge (after applying a safety voltage for the Li-ion batteries). If the hysteresis is detected is assumed a NiCd/NiMH type, otherwise the battery is Li-ion and it starts its corresponding charge regime.

3. EV/HEV CHARGING STATION

A charging station with integration of a photovoltaic generator is illustrated in Figure 1. The charging station considers a DC bus which represent an ideal bidirectional AC/DC grid tie converter, the photovoltaic PVP generator including its DC/DC converter and finally the DC/DC converter (charger) and the battery to charge. The model and control of the PVP is presented in [4] and [5]. The EMR formalism is used to organize the simulation model as presented in Figure 1 (schematic) and in Figure 2 (Simulink implementation).

2.2 Energetic macroscopic representation and modelling of the charging station

The energetic macroscopic representation EMR is a synthetic graphic tool for the systematic analysis of the interactions between subsystems in multi-physics systems. Pictograms used to represent the elements are interconnected following the action–reaction principle and respecting the integral causality. Pictograms of the EMR are presented in Appendix.

The maximal control structure MCS is deducted by direct inversion of the EMR. It allows modelling and simulating the control system. EMR has been used to study multi-physics multi-sources systems [6], [7] hybrid electrical vehicles [8] or photovoltaic generation systems [9].

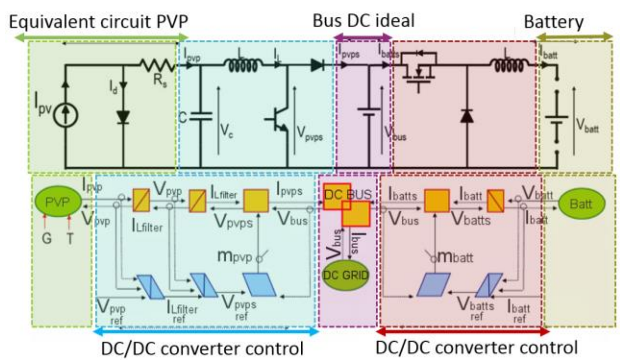
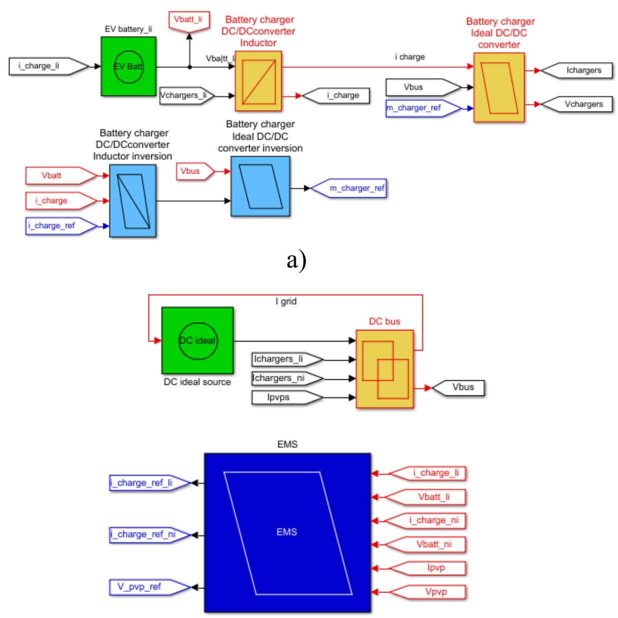


Figure 1 Scheme of the system with the REM. **Source:** [10]



a)

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Figure 2 Simulink model of the charging station. **Source:** Authors.

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4. SIMULATION RESULTS

Simulations are performed to evaluate the charging algorithms. The batteries models are those available in Matlab Simulink references: [11], [12]. The selected vehicles to charge are: Toyota Prius HEV with a bank of NiMH batteries of 288[V], 6.5[Ah], 1.31[kWh] Renault Twizy EV equipped with a bank of Li-ion batteries 60[V], 6.1[kWh] at 100 [Ah] and finally a Nissan Leaf EV equipped with a bank of Li-ion batteries with 400 [V] and 30[kWh] at 65[Ah]. The AC/DC grid-tie converter is represented with an ideal network of 24[V]. A PVP generator of 30 modules is also consider reducing the energy supplied by the grid. A daily irradiance profile to determine the PVP generation is shown in Figure 3.

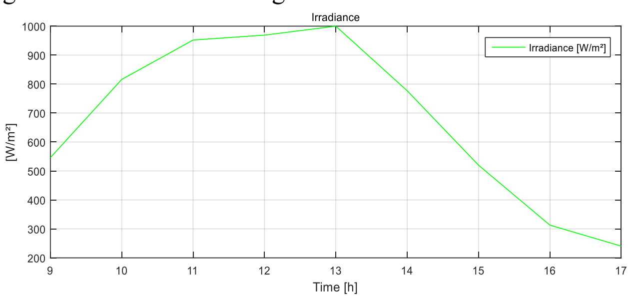
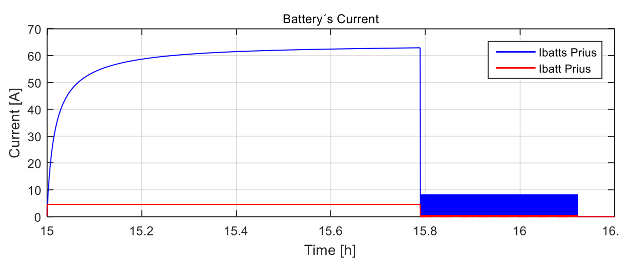


Figure 3 Daily irradiance profile. **Source:** Authors.

4.1 Toyota Prius HEV charging

Figure 4 illustrates the Toyota Prius charging with an initial state-of-charge (SOC) of 10%. It can be verified that the charge is developed in the modes described in Section 2.1.



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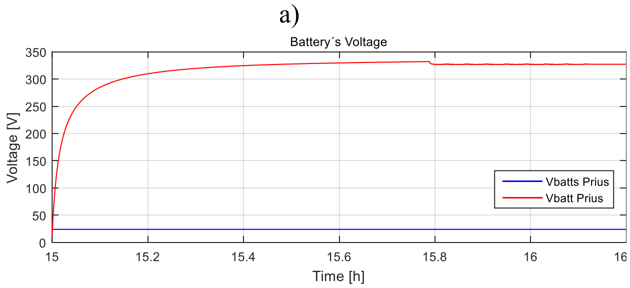
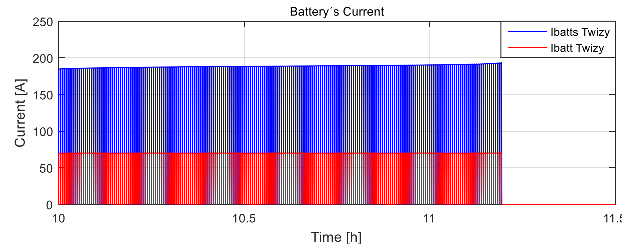


b)

Figure 4 Toyota Prius charging: NiCd/NiMH battery (a) the current, (b) the voltage. In red for the battery and in blue after the power electronic stage. **Source:** Authors.

4.3 Renault Twizy EV charging

Figure **5** illustrates the Renault Twizy charging with an initial SOC of 0.2. The discontinuities in the current are due to the frequently open circuit voltage measurement [2]. The operation modes described in Section 2.2 are verified.



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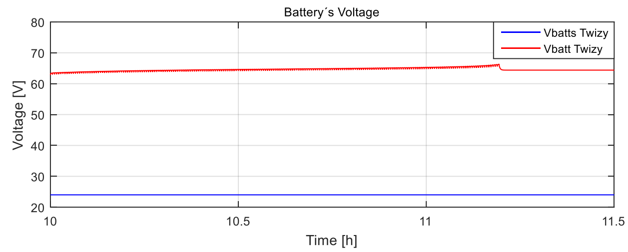
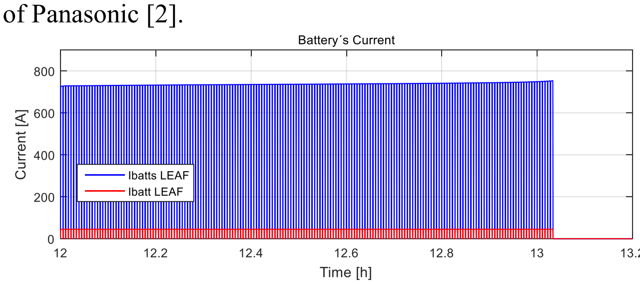


b)

Figure 5 Nissan Twizy charging. For the Li-ion battery (a) the current, (b) the voltage. In red for the battery and in blue after the power electronic stage. Source: Authors

4.4 Nissan Leaf

Figure **6** illustrates the charging of the Nissan Leaf with an initial SOC of 30% and with the charge regime of Panasonic [2].



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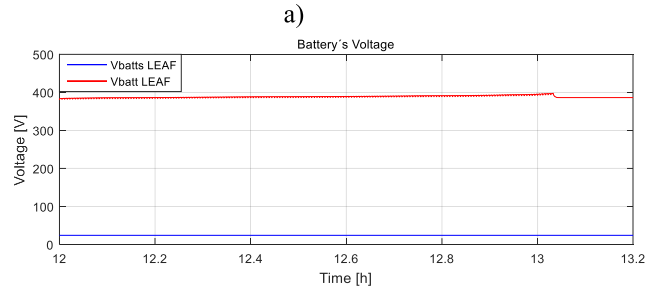


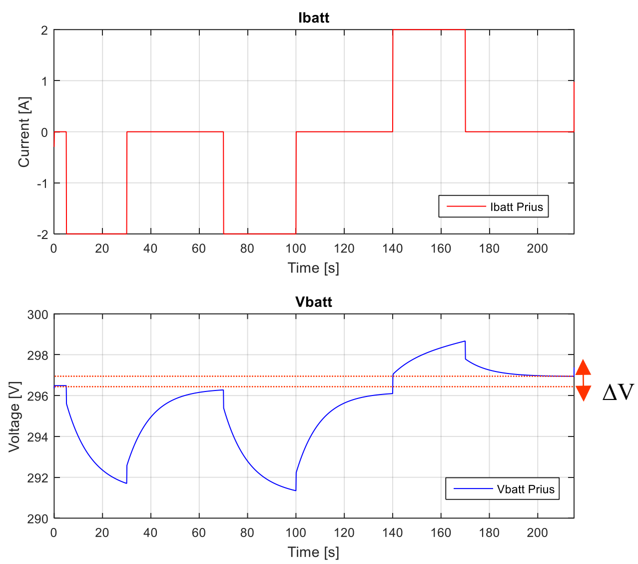
b)

Figure 6 Nissan Leaf charging. For the Li-ion battery (a) the current, (b) the voltage. In red for the battery and in blue after the power electronic stage. **Source:** Authors

4.6 Multichemistry charger

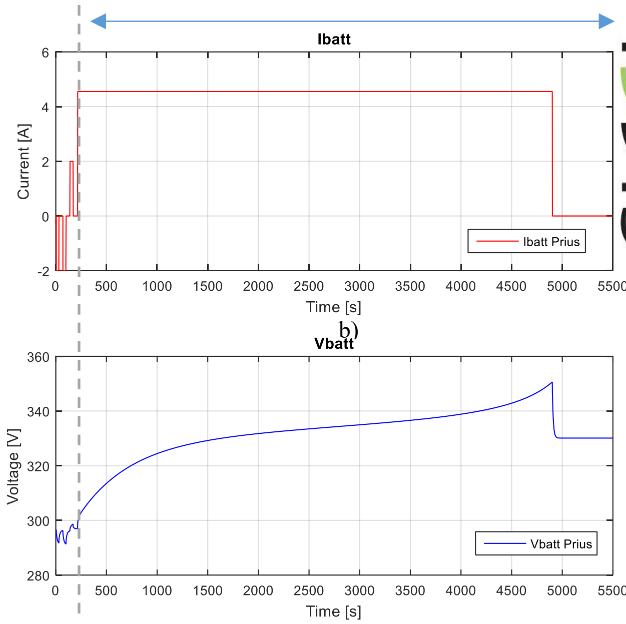
To validate the algorithm mentioned in the section 2.3 there was implemented the algorithm in Matlab in [13] as shown in where there was applied two pulses of discharge and one of discharge correspondent to 2[A] to make the hysteresis test that identifies the technology to make the charge process set in [3]. In the

Figure **7** is shown the simulation of the Prius battery in which after the detection of the delta (between the initial and final voltage during the test as in [3]) is considered as a NiCd/NiMH technology. In **Figure 8** the process of hysteresis throws a delta of voltage negligible to get start to the process of charge defined in [3].



a)

Charge



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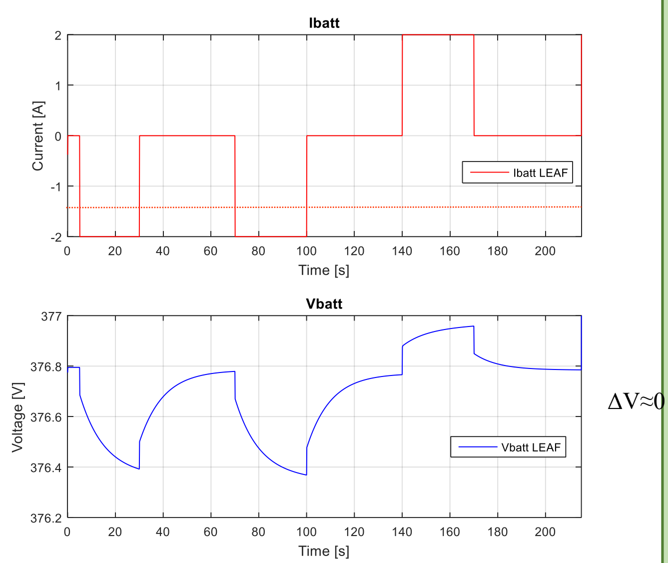
c)

Figure 7 Detection stage and charge of a NiMH battery for the Toyota Prius. (a) Hysteresis test ;(b) Current and (c) Voltage. **Source:** Authors.



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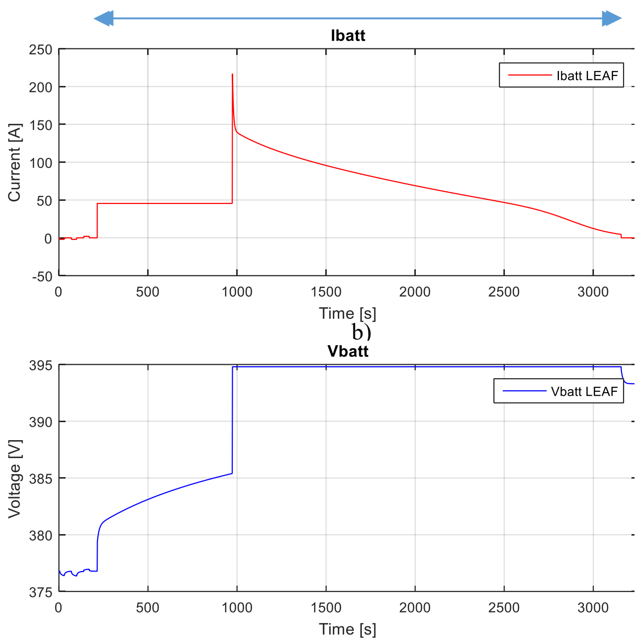

c)

Figure 8 Identification stage and charge of a Li-ion battery for the Nissan Leaf (a) Hysteresis test ;(b) Current and (c) Voltage. **Source:** Authors.

4.7 Charging station

Figure 9 shown simulation results for a charging station with integration of PVP. The Renault Twizy, a small-size electric vehicle is charged from 10 am. At 12am the Nissan Leaf a normal sized EV is recharged. Finally, the Toyota Prius HEV with a reduced size battery is charged at 3pm. The system have shown very small losses and a high efficiency as proven in [13].The algorithms implemented in the section 2.1 and 2.2 were added to the REM scheme.

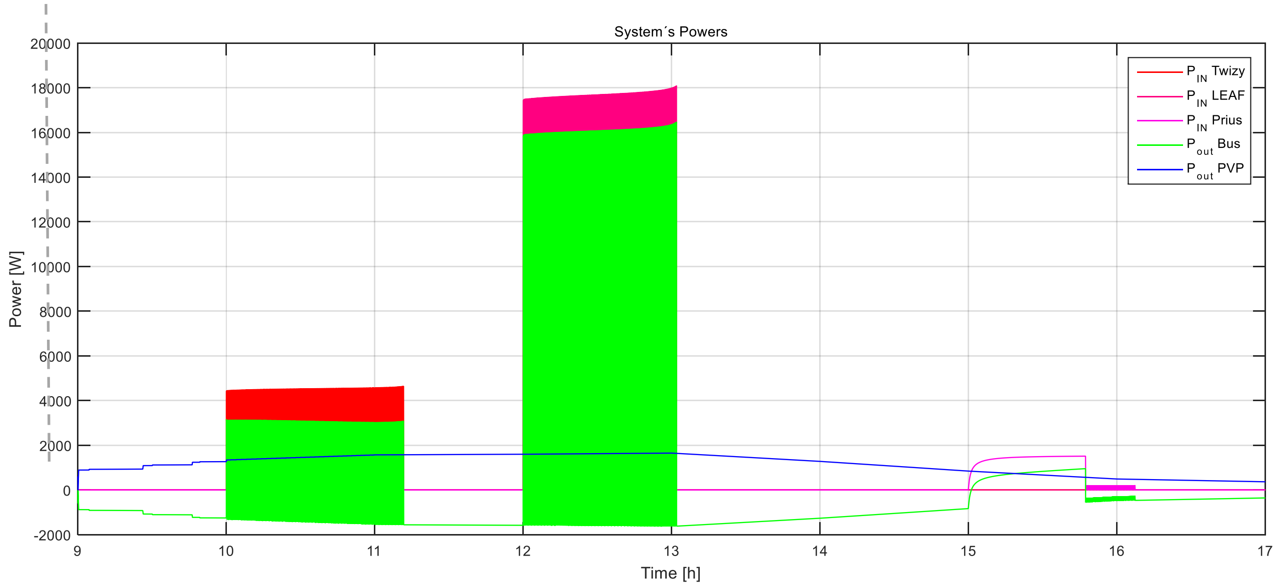

Figure 9 Power flow of the system. **Source:** Authors.

5. Conclusion

The paper presents a model for an EV/HEV charging station with integration of photovoltaic energy. Simulations are performed for the cumulative best sold EV and HEV worldwide. The charging algorithms to recharge Li-Ion and NiMH batteries are discussed, implemented and simulation results are presented.

All the algorithms implemented in the Simulink Matlab software were evaluated for the conditions established in [1] and [2].

6. References

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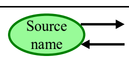
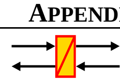
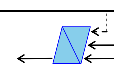
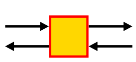
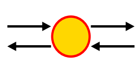
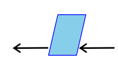
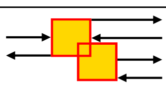
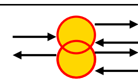
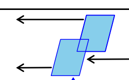
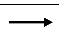
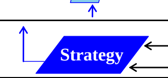
APPENDIX: EMR PICTOGRAMS

	Energy source (ex. battery)		Energy accumulation (ex. inertia)		Closed loop control
	Mono-physical converter (ex. gearbox)		Multi-physical converter (ex. pump)		Open loop control
	Energy distribution (same domain)		Energy distribution (several domain)		Coupling inversion with distribution criteria
	Action – Reaction variables		Sensor		Global energy management