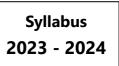


# **GENERAL INFORMATION**

Data of the subject		
Subject name	Electric Power Systems Control	
Subject code	DIE-MII-531	
Mainprogram	Official Master's Degree in Industrial Engineering	
Involved programs	Máster Universitario en Ingeniería Industrial [First year]	
Level	Intercambio	
Quarter	Semestral	
Credits	4,5 ECTS	
Туре	Obligatoria	
Department	Department of Electrical Engineering	
Coordinator	Luis Rouco Rodriguez	
Office hours	By appoinment	

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# **DESCRIPTION OF THE SUBJECT**

Contextualization of the subject		
Prerequisites		
Knowledge of electric power systems		

# **Course contents**

Contents			
Theory			
I. Introduction			
<ol> <li>Power flows in AC systems. Series and shunt compensation</li> <li>DC transmission versus AC transmission</li> </ol>			
2. An overview on power semiconductor switches			
<ol> <li>Line-commutated devices vs self-commutated devices: Thyristors and IGBTs.</li> <li>Limitations of Si-based semiconductors.</li> <li>New alternatives</li> </ol>			
3. Line-commutated FACTS (the first generation)			
1. Thyristor Controlled Reactor (TCR).			

- 2. Thyristor Switched Capacitor (TSC).
- 3. Static Var Compensator (SVC).
- 4. Thyristor Controlled Series Capacitor (TCSC).

# 4. Self-commutated FACTS (the second generation)

- 1. Voltage Source Converters: voltage and current control, power-flow control and beyond.
- 2. STATic -synchronous- COMpensator (STATCOM).
- 3. STATCOM vs SVC.
- 4. Static Series Synchronous Compensator (SSSC).
- 5. Series + shunt compensator: the Unified Power Flow Controller (UPFC).

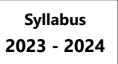
## 5. Power flow with control elements

- 1. Power flow with on load tap changing transformers.
- 2. Power flow with phase shifter transformers.

## 6. Optimal power flow

1. Problem formulation.





- 2. Objective funcions.
- 3. Euqality and inequality constraints.
- 4. Solution methods.

### 7. Security analysis

- 1. Contingency analysis.
- 2. Corrective actions.

## 8. Power flows with FACTS devices

- 1. Shunt device control in the power flow solution.
- 2. Series device control in the power flow solution.
- 3. Hybrid device control in the power flow solution.

#### 9. Stability

- 1. Large-disturbance stability of a synchronous machine connected to an infinite bus.
- 2. Small -disturbance stability of a synchronous machine connected to an infinite bus.

### 10. Stability enhancement with FACTS devices

- 1. Large-disturbance stability enhancement of a synchronous machine connected to an infinite bus by shunt and series compensation.
- 2. Small-disturbance stability enhancement of a synchronous machine connected to an infinite bus by shunt and series compensation.

## 11. High Voltage DC (HVDC) transmission based on line-commutated converters

- 1. Components of an LCC-HVDC link.
- 2. AC/DC conversion with thyristors.
- 3. Control of a HVDC link.
- 4. Current harmonics.
- 5. Reactive power requirements.

#### 12. High Voltage DC (HVDC) transmission based on self-commutated converters

- 1. Components of an LCC-HVDC link.
- 2. AC/DC conversion with self-conmutated converters.
- 3. Control of a HVDC link.
- 4. Multi-terminal HVDC links.
- 5. Comparison brtween LCC-HVDC and VSC-HVDC.

#### 13. Power flows with HVDC links

- 1. LCC-HVDC control in the power flow solution..
- 2. VSC-HVDC control in the power flow solution.

14. Stability enhancement with HVDC links





- 1. Large-disturbance stability enhancement by a parallel LCC-HVDC link.
- 2. Small-disturbance stability enhancement by a parallel LCC-HVDC link.
- 3. Large-disturbance stability enhancement by a parallel VSC-HVDC link.
- 4. Small-disturbance stability enhancement by a parallel VSC-HVDC link.

## Laboratory

Session 1: Dynamic simulation of a STATCOM using Simulink

Modeling and simulation of a STACOM Matlab-Simulink. Control loops. Performance analysis of a STACOM.

Session 2: Power flow solution with control elements using PSS/E

Power flow with a STACOM. Power flow with a phase shifter transformer. Power flow with a SSSS.

Session 3: Dynamic simulation using PSS/E

Steps of dynamic simulation with PSS/E. Dynamic simulation with PSS/E using Python scripts.

Session 4: Dynamic simulation with shunt FACTS devices using PSS/E

# **EVALUATION AND CRITERIA**

Evaluation activities	Evaluation criteria	Weight
Exams	<ul><li> 30% Mid-term exam</li><li> 70% Final exam</li></ul>	75
Laboratory	<ul><li>70%: Laboratory sessions</li><li>30%: Laboratory exam</li></ul>	25

## Grading

## Ordinary call

Theory: 75%

-30% Mid-term exam

-70% Final exam

Laboratory: 25%

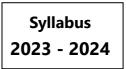
-70%: Laboratory sessions

-30%: Laboratory exam

Grades of both theory and laboratory must be greater than 5 out of 10

Class attendance is mandatory according to Article 93 of the General Regulations (Reglamento General) of Comillas Pontifical University and Article 6 of the Academic Rules (Normas Académicas) of the ICAI School of Engineering. Not complying with this requirement may





have the following consequences: students who fail to attend more than 15% of the lectures may be denied the right to do the final exam (and even the retake exam)

## **Extraordinary call**

Theory: 75%

-30% Mid-term exam

-70% Final exam

Laboratory: 25%

-70%: Laboratory sessions

-30%: Laboratory exam

Grades of both theory and laboratory must be greater than 5 out of 10

If the grade of the laboratory is greater than 5 in the ordinary call, laboratory has not to be retaken

## **BIBLIOGRAPHY AND RESOURCES**

### **Basic References**

P. Kundur, Power System Stability and Control. Mc Graw Hill, 1993.

## **Advanced References**

- N.G. Hingorani and L. Gyugui. Understanding FACTS. Concepts and technology of flexible AC transmission sytems, IEEE Press. 1999
- P. García Gonzalez and A. García Cerrada. Transporte flexible de la energía eléctrica en corriente alterna. Anales de Mecánica y Electricidad, Nov-Dic. 2004. pp 59-66.
- A. Yazdani and R. Iravani. Voltage-Sourced Converters in Power Systems. Wiley-IEEE Press, 2010.
- N.R.Chaudhuri, B. Chaudhuri, R. Majumder and A. Yazdani. Multi-terminal Direct-Current Grids: modelling, analysis and Control. Wiley-IEEE Press, 2014.
- Cigre Study Committee B4, "HVDC and Power Electronics", http://b4.cigre.org/

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