ELECTRICAL SYSTEMS FOR SUSTAINABLE DEVELOPMENT
A.A. 2020/2021

Denominazione insegnamento	ELECTRICAL SYSTEMS FOR SUSTAINABLE DEVELOPMENT	
Codice insegnamento	27000377	
Corso di Studio (CdS)	ENVIRONMENTAL AND TERRITORIAL SAFETY ENGINEERING	
Livello CdS		
Codice CdS	0790	
Settore Scientifico Disciplinare (SSD)	ING-IND/33	
Crediti Formativi Universitari (CFU)	6	
Tipologia Attività Formativa (TAF)	CARATTERIZZANTE/Affine	
Tipo attività formativa	COMPULSORY	
Anno di corso	1	
Periodo didattico	First semester	
Docente responsabile	BARONE GIUSEPPE	
Altri docenti coinvolti	-	
Organizzazione didattica*	***Ore Lezioni***	36
	Ore Esercitazioni	12
	Ore Laboratorio	-
	Ore Studio individuale	102
Lingua di insegnamento	ITALIAN	
Propedeuticità	-	
Prerequisiti	Knowledge of the notions covered in the Electrical Systems course of three-year degrees.	
Contenuti	The awareness of both ordinary citizens and political decision-makers has been affirming for several decades that the availability of energy, in the form of electricity, is a vital factor in all areas of human life, so much so that, if electric energy is lacking modern society stops. The widespread penetration of electricity in both civil and industrial activities continues incessantly, so much so that it is now customary to say that the "world becomes more and more electric" and that it tends towards the "all-electric". The trend towards the "all-electric" is also the result of the energy transition underway towards complete decarbonisation and a progressive abandonment of fossil sources as primary sources of energy for the benefit of an ever greater penetration of Renewable Energy Sources. In this scenario, the knowledge of Electrical Systems for Sustainable Development becomes very important and often crucial in the training of an engineer, both for the analysis of the functioning of the current electrical system, taking into account all the current problems introduced by the growing and widespread distributed generation with particular reference to renewable energy sources. In particular, in consideration of the evolution of the global energy context, the technologies and systems for generating and transforming electricity are proposed during the course, the aggregate systems contemplating distributed storage systems (of different technology and size) also introducing the concept of the Energy Community and considering the presence of the emerging Smart Grids. The training of the student, therefore, is aimed at obtaining a professional with the adequate knowledge of the Electrical Systems for Sustainable Development which has now become common use, but also with a very strong additional component of innovative knowledge that evolves over time and which is continuously updated, in order to allow its direct insertion in the labor market and in particular in the context of modern electro-energy	

	systems having a pivotal role in the current energy transition. During the course, the basic tools are provided to allow the student, once he has obtained his master's degree, to be able to try his hand in professional life with the problems connected with the production, transport, distribution and rational use of electricity or to try their hand at Electricity Systems for Sustainable Development, to optimize the use of energy resources based on both traditional and renewable energy sources (in particular, not programmable) and on the use of modern storage systems, both distributed and centralized in combination with current rules and always updated during the course, relating to the electricity market. Finally, the course will provide the analysis tools, the mathematical bases and the necessary knowledge of current technologies, to understand the Electric Systems for Sustainable Development, with particular reference to the emerging Smart Grids and the static energy conversion systems that can be subject of professional activity. In particular, the student will be provided with the ability to assess the environmental impact of the different practicable solutions, in terms of greenhouse gas emissions, problems related to dispatching and the programmability of the production and consumption of electricity. Aspects that are increasingly critical given the increasing spread of distributed generation, centralized and distributed storage systems, the strong expansion of electric traction and therefore the need to have recharging infrastructures available, therefore the student will be able to evaluate the electricity grid services that these new infrastructures must be able to provide.
Obiettivi formativi (in termini di risultati di apprendimento attesi)	Knowledge and understanding The student will acquire knowledge and understanding of the mechanisms that regulate the functioning of sinusoidal electric power systems, the national electricity system, the renewable energy sources, the static conversion systems used in them, the structure of the electricity grids and their evolution towards smart-grids. Furthermore, the student will acquire knowledge on the electricity market and on the dispatching of energy sources, with particular reference to techniques for optimizing and reducing the environmental impact in the production, transmission and distribution of electricity, and to the evolution of electrical systems, the peculiarities associated with the diffusion and use of generation systems from renewable energy sources and storage systems and their integration within the electrical system for network support. Knowledge and understanding applied The student will be able to apply his knowledge and understanding to analyze sinusoidal electric power systems, static energy conversion systems for renewable energy sources applications, optimal dispatching of energy sources in a smart grids way. The student must be able to demonstrate a professional approach to modeling an electrical power system, in particular he will be able to evaluate the beneficial effect, in terms of greenhouse gas emissions, of a generation plant from renewable energy sources, with or without the use of storage systems. Judgment autonomy The student will be able to evaluate the applicability of theorems and methods for the analysis of electrical power systems both in steady state and in dynamic behavior, will be able to build the related distributed parameter model of the electrical system to be studied. He will have

	developed his own autonomy of judgment which will allow him to clearly express technical concepts inherent in the study of electrical systems and will be able to solve circuit problems never previously solved. Finally, the student will have developed the ability to critically evaluate the results obtained, with particular reference to the energy supply of a building, in order to be able to evaluate and choose the best solutions for the benefit of a lower environmental impact of man's work. Communication skills The didactic approach adopted and the methods of ascertaining the knowledge acquired, will make the student able to communicate notions and methods learned, as well as to formalize the problems in terms of circuit models, economic models and with a lower environmental impact, and to discuss the related solutions to specialist and non-specialist interlocutors. Ability to learn The teaching approach of the course is developed in such a way as to allow the student to integrate the knowledge acquired in other courses (in particular the preparatory or related ones) and from sources outside the university, in order to achieve a broad vision of the related problems analysis, study of electrical power systems and their environmental impact on the ecosystem in which they will be built. This approach will allow him to develop the skills necessary to face subsequent teachings with a high degree of autonomy.
Programma	Introduction to the Electric Systems for Sustainable Development (SESS) course, description of the aims of the course and the importance of modern Electric Systems (SE) in the energy transition towards decarbonisation. A brief history of the evolution of the SEs up to our days and the relevance of modern SEs The world energy situation, with particular reference to the European and national context. The Electric Power System (SEP), the operation of the electricity transmission and distribution network. The mutation of the electricity system with the advent of Distributed Generation (GD) and the massive use of Renewable Energy Sources (RES). **Principles of circuit theory and electrical systems:** Concept of electric current. Quasi-stationary and stationary regime. Reference lines and conventions. Knots and pseudo-knots. Kirchoff's law to currents (LKC). Concept of electric potential and electric voltage. Hints on the concept of a potential gradient. Electric voltage in the presence of a conservative and non-conservative electric field: the "electric potential" function. Quasi-stationary regime and Kirchoff's law to tensions. Definition of N-Polo; Definition of N-Bipole. User (or load) and generator convention at the door of an n-bipole. Power "absorbed" or "delivered" by a port of an n-bipole according to the convention adopted. Stationary regime. Main bipoles used in steady state circuits and their constitutive bonds. Ideal resistor. Ideal generator of f.e.m .. Ideal short circuit. Ideal power generator. Ideal open circuit. Circuit resolution by applying Kirchoff's laws. Principle of superposition of effects. Bipole equivalent to a network of bipoles seen from two nodes (terminals). Series and parallel connection of two or more bipoles. Some particular examples of series and parallel of two bipoles: series between an ideal emf generator and one resistor, series of two or more

	resistors, parallel of two or more resistors etc. The method of nodal potentials. Millman's theorem. Static characteristic of a bipole: Voltage controllable bipole; Current controllable bipole; Linear bipole; Inert bipole; Passive bipole; Active bipole. Substitution Theorem. Thevenin and Norton theorem. Non Linear Component: the Diode. The Photovoltaic Cell; mismatching; By-pass diode; Blocking Diode. Royal f.e.m. generator Voltage drop. Performance of a System. Performance at Maximum Power. Ideal transformer; transformation ratio. Search for the maximum power point (MPPT). Ideal inductor. Trend of voltage and current in an inductor. Inductive reactor. Ideal condenser. Trend of voltage and current in a capacitor. Capacitive reactance. RLC circuit series. Resonance series. Pulsation and resonant frequency. Permanent sinusoidal regime. Set of complex numbers. Cartesian, trigonometric, exponential and polar notation. Symbolic representation. The phasors. Vector diagram. Impedance of resistor, inductor and capacitor. Effective value. RMS value of a sinusoidal quantity. Calculation of the instantaneous power in sinusoidal regime. Active, Reactive and Apparent Power. Power for a Resistor, Inductor and Capacitor. However variable speed: Special case Permanent sinusoidal speed. Complex power for a generic impedance. Rating data of a three-phase load. Industrial voltage drop. Power factor correction of the load. Definition of three-phase system. Equivalent single-phase circuit. Three-phase systems: line currents, phase currents, phase-to-phase voltages, phase voltages. Three-phase systems with neutral. Use of three-phase systems instead of single-phase ones for energy transmission. Any (or Transitional) Regime. Bipole Switch. Structural perturbations. Linear 1st order differential equation with constant coefficients. Associated homogeneous differential equation. Components with Memory: Inductor and capacitor. **Principles of electrical systems for energy and electrical power systems:** Optimal dispatching of thermoelectric generation powers both in a vertically integrated system and in the free market. Optimal Power Flow and functional equality constraints, functional inequality constraints, network inequality constraints, constraints on nodal stresses, constraints on the maximum admissible phase shift. Notes on the regulation of frequency, power and voltage. Possible operating states of a SEP. Analytical and graphic solution of Optimal Dispatching. Hints on the representation of the transmission line, lines (overhead and in cable) with distributed neutral, overhead lines with neutral grounded, lines (overhead and in cable) with isolated neutral or grounded by impedance. Notes on safety in direct and indirect contacts. **Principles of systems for energy conversion for renewable sources:** Notes on the different forms of energy conversion. Static energy conversion: DC / AC and AC / DC converters (single-phase and three-phase inverters) and Pulse Wide Modulation (PWM) techniques. **Renewable source plants and their connection to the electricity grid:**

	Photovoltaic systems. From the photovoltaic cell to the photovoltaic field. Peculiarities of photovoltaic inverters for grid-connected (current controlled) and stand-alone (voltage controlled) solutions. Storage systems integrated into the photovoltaic inverter or interfaced to the grid with an autonomous bidirectional inverter. **Smart-grid and storage systems for the energy transition:** The evolution of the electricity grid towards smart grids. Introduction to emerging paradigms: smart grids, super-grids and micro-grids. Capacity and power supply services, generation adequacy, load balancing. Role of ICT for smart grids. Layered representation based on power flows and information flows. Virtual Power Plant and Energy Community. Integration of floating renewable energy in transmission and distribution systems. Demand management: technologies for managing the electrical load. Customer interactions with smart metering systems, controllable load assessment. Thermostatically controlled loads, aggregate residential loads. Concepts and programs of "demand response", flexibility of demand, impact of demand management on customer choices. The different generation systems, traditional and from RES. Storage systems and their use in the distribution network. The different categories of users (active and passive) envisaged by the regulations (CEI 0-16 and CEI 0-21), the possible evolutions (energy communities). The problems associated with the strong penetration of GD and the security problems of LV and MV networks in the presence of flow inversion: unwanted off-grid networks. RES generation plants connected to the electricity grid and power transfer. The importance of energy efficiency and the quality of the service. Reduction of greenhouse gas emissions linked to the use of RES based on the environmental objectives of international climate protocols. The importance of storage systems in the evolution of the modern SEP, Energy Communities and Virtual Energy Districts, distributed and centralized storage. Storage in electric traction, problems related to charging structures and infrastructures, the concept of Vehicle to Home (V2H), Home to Vehicle (H2V), Vehicle to Grid (V2G), Grid to Vehicle (G2V), smart systems charging and fast charging, with reference to private vehicles and public transport. Life-Cycle Assessment (LCA) analysis between traditional energy sources and RES, benefits associated with different energy sources and their environmental impact.
Modalità di erogazione	FRONT
Metodologie didattiche	Both lessons and exercises are carried out in the traditional way on the blackboard. The lessons can also be held remotely in synchronous streaming mode.
Metodi e criteri di valutazione dell'apprendimento	The exam consists of a written test and an oral test. The final mark is out of thirty. Those who reach the sufficiency, on every single argument/exercise, of the written test can take the oral test. The final mark is assigned at the end of the interview which focuses on various parts of the program, especially those complementary to those contained in the written test. The oral test questions therefore allow you to complete the verification of the expected learning outcomes. If necessary, in the case of distance learning, the tests will consist of a written and an oral test, using the same topics and evaluation criteria as the test in attendance.
Testi di riferimento ed eventuali letture	• F. Iliceto, Impianti Elettrici, Vol. 1" PÀTRON Editore, Bologna 1981

consigliate	• B.F.Wollemberg, Power Generation, Operation and Control, JohnWiley&Sons, New York, 1996 • A. Paolucci, Lezioni di impianti elettrici, prima parte aggiornata, CLEUP Editore, Padova 1997. • F. Saccomanno, Sistemi elettrici per l'energia - analisi e controllo, UTET, collezione di elettrotecnica ed elettronica. • James Momoh, "Smart Grid: Fundamentals of Design and Analysis", Wiley, IEEE • D. Menniti, A. Pinnarelli, N. Sorrentino, A. Burgio, G. Brusco, Sistemi elettrici per l'energia. Analisi dei guasti e degli squilibri nelle reti trifasi simmetriche, Centro editoriale e librario, università della Calabria, 2014.
Peer review	*(Opzionale. Indicare i docenti con i quali ci si confronta su tracce, modalità di esame e impegno studente)*
Orario delle lezioni	http://diam.unial.it
Calendario degli esami	http://diam.unial.it
Commissione d'esame	http://diam.unial.it

***Organizzazione didattica**

STIMA DEL CARICO DI LAVORO PER LO STUDENTE				
	Lessons [Hours]	Exercises [Hours]	Laboratory [Hours]	Individual study [Hours]
The world energy context, the electrical power system, the evolution of the electricity system towards smart grids, distributed generation and renewable sources. The connection to the network of plants from renewable sources and the reference regulations. Energy communities, Virtual Power Plants and the importance of centralized and distributed storage systems. The role of ICT in smart grids. The controllable loads, demand response programs. James Momoh, "Smart Grid: Fundamentals of Design and Analysis", Wiley, IEEE	6	-	-	5
Fundamental concepts of electrical engineering: Voltage, current, conventions, Kirchoff's laws, elementary bipoles (linear and non-linear), equivalent bipoles, voltage-current characteristics. Fundamental theorems of electrical engineering: Thevenin and Norton, Tellegen, Principle of superposition of effects, Method of nodal potentials and Millman's Theorem. C.A. Desoer, S. Kuh, Fondamenti di Teoria dei Circuiti, Ed. Franco Angeli G. Someda, Elettrotecnica Generale, Ed. Patron Editore Bologna Merigliano, lezioni di Elettrotecnica, Vol. II, Ed. CEUP	6	3	-	21
Circuits in steady state and in permanent sinusoidal regime. First order transients in quasi-steady state. Steady-state and sinusoidal electrical power, active, reactive and apparent electrical power, power factor. Single-phase and three-phase sinusoidal regime. C.A. Desoer, S. Kuh, Fondamenti di Teoria dei Circuiti, Ed. Franco Angeli G. Someda, Elettrotecnica Generale, Ed. Patron Editore Bologna Merigliano, lezioni di Elettrotecnica, Vol. II, Ed. CEUP	6	5	-	22
Electricity conversion systems. Static electricity conversion systems and operating principles James Momoh, "Smart Grid: Fundamentals of Design and Analysis", Wiley, IEEE	6	2	-	18
The structure of the electrical power system, its evolution over time and its characteristics. The management and control of the traditional power electrical system. Power dispatching in the electrical power system. Study of power flows: load flow and optimal power flow. F. Iliceto, Impianti Elettrici, Vol. 1” PÀTRON Editore, Bologna 1981 A. Paolucci, Lezioni di impianti elettrici, prima parte aggiornata, CLEUP Editore, Padova 1997. B.F.Wollemberg, Power Generation, Operation and Control, JohnWiley&Sons, New York, 1996 F. Saccomanno, Sistemi elettrici per l'energia - analisi e controllo, UTET, collezione di elettrotecnica ed elettronica.	6	2	-	18
Benefits of renewable energy sources compared to traditional ones, Life-Cycle Assessment analysis. Reduction of greenhouse	6	-	-	18

gas emissions. The representation and structure of the electrical lines of the electrical power system. The parasitic effects and losses along the lines. Types of lines. Electrical safety.				
James Momoh, "Smart Grid: Fundamentals of Design and Analysis", Wiley, IEEE F. Iliceto, Impianti Elettrici, Vol. 1" PÀTRON Editore, Bologna 1981 A. Paolucci, Lezioni di impianti elettrici, prima parte aggiornata, CLEUP Editore, Padova 1997. D. Menniti, A. Pinnarelli, N. Sorrentino, A. Burgio, G. Brusco, Sistemi elettrici per l'energia. Analisi dei guasti e degli squilibri nelle reti trifasi simmetriche, Centro editoriale e librario, università della Calabria, 2014.				
TOTALE	**36**	**12**	**-**	**102**
Hours	✓ **150**			