TITOLO E ABSTRACT TEMA DI RICERCA DOTTORANDI DEL CORSO DI DOTTORATO DI RICERCA IN INGEGNERIA INDUSTRIALE

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XLI ciclo

Mattia Braggio

Tema di ricerca:
Un Sistema di Supporto alle Decisioni per la Manutenzione Sostenibile nell'Industria 4.0./A Decision Support System for Sustainable Maintenance in Industry 4.0.

Abstract:
La ricerca si fonda sullo sviluppo di DSS per la manutenzione, progettati esplicitamente per sfruttare le tecnologie Industry 4.0 al fine di migliorare sia l'efficienza produttiva sia la sostenibilità industriale. Piuttosto che affrontare le tecnologie in modo isolato, il lavoro si concentra sulla loro integrazione strutturata all'interno dei framework decisionali per la gestione della manutenzione. Dal punto di vista metodologico, la ricerca combina modellazione data-driven e analisi a livello di sistema per supportare la selezione delle politiche manutentive. I dati di condition monitoring raccolti dagli asset industriali vengono utilizzati per caratterizzare i comportamenti di degradazione e generare capacità predittive, che vengono successivamente integrate nella logica dei DSS. Tali input sono combinati con indicatori di prestazione relativi non solo all'affidabilità e ai costi, ma anche all'impatto ambientale (ad esempio consumo energetico e utilizzo delle risorse) e alle condizioni operative. Il DSS viene sviluppato come un framework di decisione multicriterio capace di confrontare strategie manutentive alternative in differenti scenari operativi. Una caratteristica chiave dell'approccio è l'inclusione delle dimensioni di maturità organizzativa e tecnologica, che consente al sistema di raccomandare soluzioni fattibili e consapevoli del contesto, anziché soluzioni idealizzate.

The research is grounded in the development of DSSs for maintenance, explicitly designed to leverage Industry 4.0 technologies to enhance both production efficiency and industrial sustainability. Rather than addressing technologies in isolation, the work focuses on their structured integration within decision-making frameworks for maintenance management. Methodologically, the research combines data-driven modelling and system-level analysis to support maintenance policy selection. Condition monitoring data collected from industrial assets are used to characterize degradation behaviors and enable predictive insights, which are then embedded into DSS logic. These inputs are integrated with performance indicators related not only to reliability and cost, but also to environmental impact (e.g., energy consumption and resource use) and operational conditions. The DSS is developed as a multi-criteria decision-making framework capable of comparing alternative maintenance strategies under different operational scenarios. A key feature of the approach is the inclusion of organizational and technological maturity dimensions, allowing the system to recommend feasible and context-aware solutions rather than idealized ones.

Emanuele Corongiu

Tema di ricerca:
Monitoring of transient events in nuclear fusion machines by machine learning

Abstract:
The PhD project aims to develop non-intrusive diagnostic tools, based on Machine Learning (ML) for the real-time monitoring and/or control of magnetically confined fusion (MCF) devices. Overcoming the computational limitations of traditional off-line physical models, the research employs data-driven and physics-informed approaches to identify anomalous transient events in fusion plasmas, analyzing data collected from the diagnostics of various experimental MCF machines. The research areas include the prediction of disruptions in the AUG and JET tokamaks, the detection of thermal overloads in the W7-X stellarator, the monitoring of detachment in the AUG tokamak, and the prediction of the current for the suppression of parasitic magnetic fields in ITER's neutral beam injector. At the heart of these activities lie machine learning methods, which are the primary tool for resolving complex direct and inverse problems.

Filippo Fois

Tema di ricerca:
Robotica Industriale ed IA per l'interazione uomo-macchina/Industrial Robotics and AI for Human-Machine Interaction

Abstract:
Il progetto di ricerca punta a sviluppare sistemi di controllo per robot industriali e collaborativi, che possono permettere l'interazione uomo-macchina sicura in ambito lavorativo-industriale. Questi sistemi di controllo sono sviluppati sulla base di algoritmi di Visione Artificiale, algoritmi di Deep Learning che permettono a sistemi non sensorizzati di poter utilizzare elementi come videocamere per ricevere dati e analizzare segnali video e immagini e, grazie a questi operare in supporto al robot per permettergli di non recar danno all'operatore umano durante la lavorazione congiunta, e di permettere l'effettiva collaborazione in ambito lavorativo tra operatore umano e robot senza sistemi di recinzione fisici, ma virtuali grazie ai vari sistemi di controllo che lavorano con Intelligenze Artificiali che permettono, di raggiungere tale obiettivo. I sistemi saranno sviluppati prevalentemente in ambiente di programmazione Python in unione agli ambienti di programmazione del robot e delle attrezzature di supporto selezionate, la metodologia di sviluppo prevede il monitoraggio continuo della posizione dell'operatore tramite marker digitali posti sul corpo dell'operatore (focus su posizione di mani e volto), il monitoraggio delle fasi e degli oggetti della lavorazione, la definizione di zone a diverso coefficiente di rischio sul piano di lavoro e l'adattamento automatico delle traiettorie del robot in funzione della distanza dalle aree critiche.

The research project aims to develop control systems for industrial and collaborative robots, which can enable safe human–machine interaction in industrial work environments. These

control systems are developed on the basis of Artificial Vision algorithms, Deep Learning algorithms that allow non-sensorized systems to use elements such as cameras to receive data and analyze video signals and images and, thanks to these, operate in support of the robot to prevent it from causing harm to the human operator during joint processing, and to enable effective collaboration in the workplace between the human operator and the robot without physical fencing systems, but virtual ones thanks to the various control systems that work with Artificial Intelligences that make it possible to achieve this objective. The systems will be developed mainly in the Python programming environment together with the programming environments of the robot and the selected support equipment. The development methodology includes the continuous monitoring of the operator's position through digital markers placed on the operator's body (focus on the position of hands and face), the monitoring of the phases and objects of the processing, the definition of zones with different risk coefficients on the work surface, and the automatic adaptation of the robot's trajectories based on the distance from critical areas.

Erika Maiocchetti

Tema di ricerca:
Sviluppo di metodi di modellizzazione e analisi del segnale per applicazioni di fotometria su fibra ottica in neurobiologia/Development of Signal Modeling and Analysis Methods for Fiber Photometry Applications in Neurobiology

Abstract:
Questa tesi affronta la sfida dell'interpretazione di misurazioni basate sulla fluorescenza acquisite in vivo, dove i segnali biologici sono spesso confusi da rumore strumentale, artefatti fisici e variabilità sistematica. Il lavoro si concentra sullo sviluppo di metodi di modellazione del segnale e di analisi dei dati per migliorare la separazione delle dinamiche biologicamente significative dai contributi non biologici. Particolare attenzione è rivolta alle tendenze lentamente variabili e agli effetti ottici che possono distorcere l'interpretazione del segnale tra condizioni sperimentali diverse. Un elemento centrale è il confronto tra dataset veicolo e dataset ottenuti con somministrazione di farmaci, al fine di isolare la risposta biologica specifica indotta dal trattamento. Approcci orientati alla data science e tecniche di machine learning sono integrati nell'analisi, consentendo di apprendere rappresentazioni latenti del segnale e di classificare automaticamente condizioni sperimentali distinte. Il quadro risultante intende migliorare la robustezza, la riproducibilità e l'interpretabilità delle misurazioni fluorescenti, con applicazioni in studi neurobiologici e farmacologici.

This thesis addresses the challenge of interpreting fluorescence-based measurements acquired in vivo, where biological signals are often obscured by instrumental noise, physical artifacts, and systematic variability. The work focuses on developing signal modeling and data analysis methods to improve the separation of biologically significant dynamics from non-biological contributions. Particular attention is paid to slowly varying trends and optical effects that can distort signal interpretation across different experimental conditions. A central element is the comparison between vehicle datasets and datasets obtained with drug

administration, in order to isolate the specific biological response induced by the treatment. Data science-oriented approaches and machine learning techniques are integrated into the analysis, enabling the learning of latent signal representations and the automatic classification of distinct experimental conditions. The resulting framework aims to improve the robustness, reproducibility, and interpretability of fluorescence measurements, with applications in neurobiological and pharmacological studies.

Maurizio Marongiu

Tema di ricerca:
Applicazioni di convertitori multilivello modulari nelle reti ibride MVAC/DC per l'incremento della resilienza del sistema/Applications of Modular Multilevel Converters in Hybrid MVAC/DC Networks for Enhancing System Resilience

Abstract:
Questo progetto di dottorato riguarda l'applicazione di convertitori multilivello modulari nelle reti ibride MVAC/DC per incrementarne la resilienza. La crescente integrazione di fonti rinnovabili, sistemi di accumulo e carichi non lineari richiede reti di media tensione più flessibili e controllabili, capaci di gestire guasti e/o variazioni improvvise delle condizioni operative. L'attività di ricerca si concentra su modellistica e gestione di questa tipologia di convertitori che integrano diverse tecnologie di accumulo dell'energia, con, inoltre, l'obiettivo di analizzarne il funzionamento in diverse modalità operative, tra cui: grid-following, grid-forming e Soft Open Point. In questo contesto, il convertitore non è solo un'interfaccia tra sezioni AC e DC, ma un dispositivo attivo in grado di contribuire alla regolazione dei flussi di potenza, alla stabilità e al ripristino della rete. Un ulteriore obiettivo dell'attività è l'ottimizzazione delle strategie di controllo, del dimensionamento e del posizionamento del convertitore, al fine di individuare le soluzioni più efficaci per migliorare la sicurezza e la continuità di alimentazione della rete. Le attività prevedono simulazioni in diversi ambienti, tra cui MATLAB/Simulink e Hardware-in-the-loop, così da valutare il comportamento dei sistemi proposti in scenari ordinari e perturbati.

This PhD project concerns the application of modular multilevel converters in hybrid MVAC/DC networks to enhance their resilience. The increasing integration of renewable energy sources, energy storage systems, and non-linear loads requires more flexible and controllable medium-voltage networks, capable of managing faults and/or sudden changes in operating conditions. The research activity focuses on the modelling and management of this type of converter, which integrates different energy storage technologies, with the further objective of analysing its operation in different operating modes, including grid-following, grid-forming, and Soft Open Point operation. In this context, the converter is not only an interface between AC and DC sections, but an active device capable of contributing to power flow regulation, stability, and network restoration. A further objective of the activity is the optimisation of control strategies, converter sizing and siting, in order to identify the most effective solutions to improve network security and continuity of supply. The activities include simulations in different environments, including MATLAB/Simulink and

Hardware-in-the-loop, in order to evaluate the behaviour of the proposed systems under ordinary and disturbed scenarios.

Mariana Marques da Cuhna

Tema di ricerca:
Innovative approaches to CO2 valorization: process simulation, 3E assessment, and industrial application

Abstract:
Il progetto di dottorato è incentrato sullo sviluppo di un tool open source a supporto del processo decisionale per la valutazione e l'ottimizzazione dei percorsi di produzione del metanolo a livello di supply chain. Il framework integra indicatori economici, ambientali e sociali, considerando esplicitamente l'evoluzione tecnologica in funzione del Technology Readiness Level (TRL), dell'orizzonte temporale e della scala produttiva. Le tecnologie di produzione del metanolo sono classificate in base alla fonte di carbonio, alla via di sintesi e al TRL. I processi vengono scomposti in operazioni unitarie modulari, tra cui pretrattamento delle materie prime, generazione e condizionamento del syngas, sintesi e purificazione del metanolo. Per le tecnologie mature e a TRL intermedio vengono sviluppate simulazioni di processo in Aspen Plus, mentre per le tecnologie a basso TRL si utilizzano dati di letteratura. I risultati, comprensivi di bilanci di massa ed energia, costi di investimento, consumi di utility e indicatori di impatto con relative incertezze, alimentano un database strutturato. Viene inoltre proposta una nuova metodologia di learning curve, basata su un approccio probabilistico e su modelli derivati dall'analisi dei brevetti, per l'aggiornamento dinamico di costi, consumi di utility e flussi di processo nel tempo e con la scala. Il modello è infine integrato in un'ottimizzazione di supply chain e in una dashboard interattiva per l'identificazione dei percorsi di produzione del metanolo più sostenibili.

The PhD project focuses on the development of an open source decision support tool for the evaluation and optimization of methanol production pathways at the supply chain level. The framework integrates economic, environmental, and social indicators, explicitly accounting for technology learning as a function of Technology Readiness Level (TRL), time horizon, and production scale. Methanol production technologies are systematically classified according to carbon source, synthesis route, and TRL. Process routes are decomposed into modular unit operations, including feedstock handling and pretreatment, syngas generation and conditioning, methanol synthesis, and purification. For mature and mid TRL technologies, detailed process simulations are developed using Aspen Plus, while low TRL technologies are described using literature data. The resulting mass and energy balances, investment costs, utility consumption, and impact indicators are stored in a structured database, including associated uncertainty levels. A novel learning curve methodology is proposed to dynamically update costs, utilities, and process flow over time and scale, using probability and a patent-based model. The learning based process models are integrated into a supply chain optimization framework considering feedstock availability, transportation, energy sources, and policy scenarios. The final output is an interactive dashboard that identifies

optimal methanol production pathways based on user defined economic and environmental objectives.

Muhammad Saleem

Tema di ricerca:
Decentralized control in distribution networks

Abstract:
The research main expected accomplishments include the development of advanced communication protocols for smart-grid applications capable of supporting reliable and secure data exchange within active distribution networks. The research will also focus on the design of ICT-based monitoring and data-processing solutions aimed at improving the observability, flexibility, and operational efficiency of modern distribution systems. Another important objective is the creation of decentralized control methodologies for active power systems, enabling more adaptive and resilient management of distributed energy resources, renewable generation, storage systems, and active consumers. In addition, the project is expected to develop innovative algorithms to support Distribution System Operators (DSOs) in real-time grid monitoring, operation, and decision-making processes. The research activities will ultimately lead to the publication of scientific papers, conference contributions, and technical reports related to communication infrastructures, smart-grid technologies, and advanced control solutions for future power distribution networks. The position deals with a highly interdisciplinary research environment combining power systems, communication engineering, data analytics, and control technologies, while preparing the researcher for advanced academic and industrial careers in smart grids and energy digitalization

Antonella Salis

Tema di ricerca:
*Progettazione di metamateriali programmabili basati su sistemi meccanici periodici multifisici/*Design of programmable metamaterials based on multiphysics periodic mechanical systems

Abstract:
Il presente progetto di ricerca riguarda lo studio di sistemi meccanici periodici e lo sviluppo di metamateriali multifisici programmabili. I sistemi periodici, costituiti da celle unitarie ripetute nello spazio, presentano bande di non propagazione (band gap) che impediscono la trasmissione delle onde elastiche, mentre i metamateriali permettono inoltre l'emergere di proprietà non convenzionali quali anisotropia dinamica, massa e rigidezza effettive negative e fenomeni di non reciprocità. L'obiettivo è estendere i modelli classici di dispersione includendo effetti multifisici, in particolare l'interazione fluido-struttura e l'accoppiamento con campi elettromagnetici esterni, utilizzati come strumento di controllo attivo delle

proprietà dinamiche del sistema. Tale approccio consente la riconfigurazione delle frequenze di band gap e l'introduzione di comportamenti programmabili, superando le limitazioni di soluzioni basate su elementi attivi meccanici complessi. La metodologia si basa su metodi analitici basati su matrici di trasferimento, funzioni di Green e tecniche di omogeneizzazione, supportate da validazione numerica tramite simulazioni agli elementi finiti. Il progetto mira, in definitiva, a definire una nuova classe di metamateriali adattivi con possibili applicazioni nel controllo delle vibrazioni, nella protezione dinamica delle strutture e in dispositivi per lo sfruttamento dell'energia (energy harvesting), aprendo la strada a materiali intelligenti con proprietà controllabili in tempo reale.

This research project focuses on the study of periodic mechanical systems and the development of programmable multiphysical metamaterials. Periodic systems, composed of unit cells repeated in space, exhibit band gaps that inhibit the propagation of elastic waves, while metamaterials also enable the emergence of unconventional effective properties such as dynamic anisotropy, negative effective mass and stiffness, and non-reciprocal behaviour. The aim is to extend classical dispersion models by incorporating multiphysical effects, in particular fluid–structure interaction and coupling with external electromagnetic fields, which are used as a mechanism for the active control of the system's dynamic properties. This approach enables the reconfiguration of band-gap frequencies and the introduction of programmable behaviours, overcoming the limitations of solutions based on complex active mechanical elements. The methodology is based on analytical formulations based on the transfer matrix method, Green's functions, and homogenisation techniques, supported by numerical validation through finite element simulations. Ultimately, the project aims to define a new class of adaptive metamaterials with potential applications in vibration control, structural dynamic protection, and energy harvesting devices, paving the way for smart materials with real-time tunable properties.

Rayen Sellimi

Tema di ricerca:
Gemello digitale assistito dall'IA per la modellazione della catena di approvvigionamento nell'industria della produzione basata sulla CO2/AI-assisted digital twin for supply chain modelling in CO2 based production industry

Abstract:
Lo studio mira allo sviluppo della supply-chain per un network eco-industriale nel quale coesistono e interagiscono tra loro più filiere in qualche modo collegate al problema della sostenibilità, dove rifiuti urbani, biomassa e feedstock fossili costituiscono i flussi in ingresso energetici e chimici, mentre i flussi in uscita sono rappresentati da una molteplicità di prodotti, come idrogeno, metanolo, energia elettrica, soda solvay, anidride carbonica per l'impiego nell'industria. In questo senso, la supply chain non è solo una rete logistica, ma anche un sistema di allocazione dinamica delle risorse tra i nodi del cluster, con forte interdipendenza tra disponibilità delle materie prime, non sempre programmabili, capacità degli impianti e domanda finale dei prodotti. La variabilità dei flussi in ingresso è uno degli

aspetti maggiormente caratterizzanti e pone una serie di problematiche, che saranno trattati con gli strumenti del Machine Learning e l'Intelligenza Artificiale per la previsione e la riallocazione ottima delle risorse. Il modello di supply chain che il Dottorando sarà chiamato a sviluppare sarà assistito da AI sia per il funzionamento istantaneo di supporto al digital twin che come modello previsionale nel futuro. L'obiettivo ultimo è quello di considerare non solo i classici aspetti economici e ambientali, ma anche l'ottimizzazione complessiva del cluster dal punto di vista della salvaguardia della sicurezza e della sostenibilità.

The study is oriented to the supply chain development for an eco-industrial network in which multiple supply chains, somehow connected to the issue of sustainability, coexist and interact. Incoming energy and chemical flows include municipal waste, biomass, and fossil feedstocks, while outgoing flows include a variety of products, such as hydrogen, methanol, electricity, soda Solvay, and carbon dioxide for industrial use.In this sense, the supply chain is not just a logistics network, but also a system for dynamically allocating resources among cluster nodes, with strong interdependencies between the availability of raw materials, which are not always predictable, plant capacity, and final product demand. The variability of incoming flows is one of the most defining aspects and poses a series of challenges, which will be addressed using machine learning and artificial intelligence tools for forecasting and optimal reallocation of resources. The supply chain model the PhD student will develop will be AI-assisted, both for instantaneous operation to support the digital twin and as a forecasting model for the future. The ultimate goal is to consider not only the traditional economic and environmental aspects, but also the overall optimization of the cluster from the perspective of safeguarding safety and sustainability.

XL ciclo

Adriano Casu

Tema di ricerca:
Sviluppo del sistema di distribuzione elettrica per il miglioramento della resilienza

Abstract:
I cambiamenti climatici, conseguenza delle azioni antropiche degli ultimi decenni, portano inequivocabilmente a una necessità di adattamento delle società umane. Questa necessità è dovuta sia a un mutamento delle condizioni ambientali direttamente misurabili (come l'aumento della temperatura globale media), sia a un cambiamento nell'occorrenza di fenomeni climatici estremi (ondate di calore, tempeste di vento, tempeste di neve, alluvioni, incendi e terremoti). La rilevanza di tali eventi avversi è in aumento in termini di frequenza e di magnitudo. Quindi, il rischio legato ai danni che le infrastrutture realizzate dall'uomo potranno subire è in progressiva crescita. Tra le infrastrutture critiche, i sistemi elettrici sono senza dubbio tra le più vulnerabili e i loro disservizi hanno effetto su tutte le attività della società odierna. In aggiunta, l'interdipendenza del funzionamento di altre infrastrutture a rete, come ad esempio i trasporti e i sistemi di telecomunicazione con i sistemi elettrici, complica la valutazione dei rischi specifici. Per questo motivo, sono necessari strumenti capaci di valutare in maniera integrata l'esposizione delle infrastrutture critiche agli eventi climatici estremi e ai cambiamenti attesi, la loro vulnerabilità e la capacità di adattarsi per far fronte sia ad eventi improvvisi e devastanti, sia a cambiamenti lenti ma progressivi e inevitabili.
Il progetto di ricerca si pone come obiettivo lo sviluppo di uno strumento di pianificazione in grado di valutare il livello di resilienza dei sistemi elettrici in relazione ai più impattanti eventi climatici e proporre le opportune soluzioni per migliorarne le prestazioni prima, durante e dopo tali eventi, anche in relazione al possibile concomitante fallimento di altre infrastrutture che possono essere influire soprattutto sulle fasi di ripristino. A tal fine, è necessario includere nello studio lo sviluppo di scenari climatici adatti a descrivere i fenomeni in gioco con gli opportuni metodi per misurare l'impatto che tali eventi possono avere sui sistemi elettrici.

Pierluca Dessì

Tema di ricerca:
Innovative methodologies for improving the analysis and design of aeronautical components

Abstract:
The available computing power is ever increasing and it allows and it opens possibilities that could only be imagined only a decade ago. For example, the design of aeronautical components is strongly driven by computational models (such as CFD and FEA) and optimization processes. Aeronautical components are subjected to various stresses and operational conditions throughout their life cycle. It is important to be able to design these components robustly, ensuring that their performance is not heavily penalized by changes

in operational conditions or the impacts of such stresses. It is also important to monitor components during their life cycle, achieved through the development of accurate digital twins, which enable more efficient predictive maintenance. This project aims to apply artificial intelligence methodologies to the area of aeronautical components, focusing on robust design optimization (RDO) and digital twin development. It aims to develop and integrate tools to automate and improve the fidelity of CFD simulations, achieve robust design optimization, and create digital twins for monitoring in-service components. These objectives aim to accelerate design processes, lower development costs, and promote more sustainable component management.

Lorenzo Milia

Tema di ricerca:
Machine learning techniques for developing non-intrusive monitoring tools in thermonuclear fusion machines and facilities

Abstract:
The PhD project is related to the development of a Machine leaning tool for estimating the impinging heat flux distribution on the tile surface of the Short Time Retractable Instrumented Kalorimeter Experiment (STRIKE), starting from the IR camera measures on the tile back side. The work is finalized to evaluate the uniformity and divergence of SPIDER in real time, the Source for Production of negative Ion of Deuterium Extracted from Radio Frequency developed for MITICA, the full prototype of the whole ITER Heating Neutral Beams.
In addition, ML algorithms be exploited for developing an intermachine disruption predictor considering JET and ASDEX upgrade data. The activity is finalized to realize a tool able to extrapolate disruptive patterns from existing devices to next-generation tokamaks.

Maria Vittoria Iris Piro

Tema di ricerca:
Green hydrogen and fuels production from renewable feedstocks with electrochemical and bio-electrochemical technologies

Abstract:
In a world where the global population, annual worldwide energy demand and consumption of fossil fuels are steadily increasing, employing a cheap, environmentally friendly, and unlimited energy source from renewable feedstocks is one of the main challenges for humanity today, as is the transition to energy and environmentally sustainable alternatives. In this context, the use of Bio-Electrochemical Systems (BES), which are revolutionary and sustainable bio-engineering technologies for simultaneously production of energy and treatment of wastewater, has gained increasing popularity in recent decades. BES, which can be applied as Microbial Fuel Cells (MFCs) and Microbial Electrolytic Cells (MECs), offer the

possibility of using microbes for the clean and efficient production of high-value compounds such as fuel. This forms the foundation of the doctoral research that will be carried out over the next three years. Specifically, within the BES framework, the research will focus on the production of green hydrogen, a promising and sustainable energy carrier. Green hydrogen, produced through electrochemical processes driven by renewable energy sources, has gained significant attention due to its potential to decarbonise various sectors, including transportation, industry, and power generation. By exploiting the unique capabilities of BES, the aim is to enhance the efficiency and scalability of hydrogen production while simultaneously contributing to the treatment of wastewater, offering a dual-benefit approach. This research looks to explore innovative strategies to improve microbial activity, improve hydrogen yields, and integrate BES technology into real-world applications for a more sustainable and circular energy system.

Alessandro Sechi

Tema di ricerca:
Automazione della gestione della Rete di Trasmissione della regione Sardegna tramite Intelligenza Artificiale

Abstract:
Una gestione dei sistemi energetici che tenga un occhio di riguardo all'equilibrio dei parametri del Trilemma Energetico (sicurezza energetica, equità energetica e sostenibilità ambientale) non è banale. Gli interventi atti ad incrementare uno o più di questi parametri spesso comportano importanti ed onerosi investimenti strutturali e possono, in determinati casi, comportare squilibri considerevoli, tal volta anche critici, come si è potuto osservare in questi ultimi anni, ove la transizione a un sistema energetico più sostenibile sta comportando un'ardua sfida sotto molti punti di vista. Ne consegue che qualsiasi strategia che permetta un incremento delle prestazioni di un sistema energetico, tramite un'ottimizzazione della gestione delle infrastrutture attualmente esistenti, senza necessariamente richiedere grossi interventi o investimenti, siano di forte interesse, soprattutto in sistemi isolati come quello della Regione Sardegna. In questo contesto si inserisce questo progetto, che si propone lo scopo di realizzare in sistema autonomo di gestione della rete di trasmissione dell'energia elettrica regionale, tramite l'ausilio di algoritmi di Intelligenza Artificiale. Questa, una volta adeguatamente allenata tramite dati ottenuti attraverso simulazioni di Load Flow e Optimal Power Flow, sarà in grado di garantire una gestione ottimale dei flussi energetici nella rete di trasmissione grazie alla misurazione dei parametri di funzionamento della rete nei vari nodi. Tramite questo sistema si prevede di ottenere un miglioramento su tutti i parametri caratteristici del Trilemma Energetico con riferimento al sistema sardo, incrementando la resilienza della rete, e quindi la sua sicurezza, una riduzione dei costi di gestione, quindi apportando un contributo all'equità energetica rendendo meno costosa la fornitura per l'utente e, infine, un incremento della sostenibilità ambientale grazie all'ottimizzazione dei flussi energetici.

Samuele Setzu

Tema di ricerca:
Monitoraggio e diagnostica di sistemi complessi con tecniche di machine learning

Abstract:
Machine Learning (ML) has rapidly evolved into one of the most transformative technologies of the modern era, revolutionizing fields from medicine to industry by enabling data-driven decision-making and predictive analytics at an unprecedented scale. Machine learning models are not inherently explainable, and efforts are even more requested to comprehend and retrace how the models came to results.
In this project different applications from heterogeneous research fields, when data-driven approaches for solving complex problems are necessary, will be faced. In particular, applications from thermonuclear controlled fusion will be faced for machine monitoring and protection, e.g. for disruption prediction and overload detection. Moreover, application from power system monitoring and management and medical diagnosis will be faced. When possible, the project will also focus on the implementation of models that can be easily interrogated to understand the reasoning behind the model answer.

XXXIX ciclo

Samee Ullah Ansari

Tema di ricerca:
A Study of Experimental and Numerical Modeling for Green Hydrogen and Ammonia Production technology in Sustainable Transport and Energy Storage

Abstract:
A significant shift in the global energy landscape is undergoing, moving away from fossil fuels and towards sustainability. Green hydrogen represents a promising energy carrier to decarbonize transport, power generation and industrial sectors since can be generated using renewable energy sources in moments of low electricity demand and can be re-used without emitting carbon molecules into the atmosphere. Moreover, it can be used to generate a large number of carbon neutral synthetic fuels that can be employed in a variety of transport and industrial sectors where there are not any alternative carbon free technologies to replace fossil fuels.
Green hydrogen can also be used to generate green ammonia (meaning no fossil fuels and emissions are associated with its production), that can be employed as a fuel but also in agriculture, replacing urea that is conventionally produced using natural gas in an energy intensive process.
This thesis then aims to provide a novel contribution in this field by investigating cutting-edge green hydrogen production technologies such as AEM electrolysers and demonstrate the feasibility of a distributed and micro-scale ammonia production model, employing an optimised Haber-Bosch process. Numerical analysis and optimization of the two systems are carried out using software tools such as ASPEN and AVL simulation. An experimental campaign will support the numerical findings by validating the numerical models. To carry out the experimental investigation, a demonstrator is under construction and embeds 14 solar panels, a 12 kW AEM electrolyzers, a 28 kWh battery, a 12 kW inverter, a 4 kW PEM fuel cell and a 0.25 kg/h Haber Bosch unit. Such test rig will be used also to design and test several control strategies able to optimise the systems performance under intermittent operation of solar panels.

Mansoor Urf Manoo Parehar

Tema di ricerca:
Application of the Benders decomposition in Power Distribution system

Abstract:
Modern distribution networks require advanced optimization approaches to ensure safe and effective operation due to their growing complexity, which is enabled by the integration of renewable energy sources and the requirement for flexibility. In the current research, the Security-Constrained Optimal Power Flow (SCOPF) issue in distribution systems is solved using Benders decomposition. Benders decomposition provides an organized method for

tackling the difficulties of big networks by breaking down the large-scale optimization issue into smaller, easier-to-manage subproblems and a master problem. From a current standpoint, the method offers adaptability in handling voltage and current violations, enabling efficient resource use in a range of network scenarios. It creates a flexible framework to incorporate new technologies and adjust to changing operational needs from a forward-looking perspective. The technique improves the viability of solving SCOPF in complex networks by separating the master problem which deals with high-level decisions from subproblems that deal with contingencies and detailed power flow calculations. The findings show that Benders decomposition is a strategic approach to guaranteeing flexibility, dependability, and sustainability in both present and future power systems, in addition to being a useful tool for managing extensive distribution networks.

Kainat Rizwan

Tema di ricerca:
Blockchain and IoT solutions for managing innovative power systems

Abstract:
The integration of IoT devices, smart meters, Raspberry Pi, and blockchain technology is to transform the cutting-edge power systems which basically enables safe data transactions, well-organized management and more importantly dynamic energy monitoring. It is an adaptable approach which impact the flexibility of IoT-enabled devices such as Raspberry Pi which provides decentralized energy control and tracking, whereas the blockchain technology assure safe exchange of energy data, transparency, and Durability. Also the Applications integrate the smart energy meters that specify accurate analytics of consumption as well as energy management systems for auto-billing systems, industries and homes. Integration of Blockchain technology additionally facilitates peer-to-peer energy trading and also advances green energy adoption via assured smart contracts. These innovations just not only enhance working proficiency but also sustain energy goals by allowing users with data-driven insights and decentralized control over energy usage. This context confines notable potential for the development of innovative, secure, and intelligent power systems adapted to the demands of gradually interrelated world.

XXXVIII ciclo

Davide Micheletto

Tema di ricerca:
Sistemi e processi innovativi basati su idrogeno da FER e suoi derivati per la transizione energetica/Innovative energy systems and processes based on hydrogen from RES and its derivatives in the energy transition process

Abstract:
Il progetto di ricerca mira a sviluppare sistemi per la produzione di idrogeno e altri vettori energetici utilizzando energia rinnovabile. La ricerca si propone di sviluppare configurazioni impiantistiche e strategie operative per l'integrazione dell'idrogeno verde nei processi industriali attraverso lo sviluppo di modelli matematici, l'integrazione di tecnologie innovative e l'ottimizzazione dei processi. Le analisi puntano a migliorare la sostenibilità e l'efficienza dei processi industriali nella transizione energetica.

The research project aims to develop systems to produce hydrogen and other energy carriers using renewable energy. The research seeks to design plant configurations and operational strategies for integrating green hydrogen into industrial processes by developing mathematical models, integrating innovative technologies, and optimising the processes. The analyses aim to enhance the sustainability and efficiency of industrial processes in the energy transition.

Leonardo Sibono

Tema di ricerca:
Monitoring and quality assessment of food products manufacturing processes

Abstract:
La crescente consapevolezza dei consumatori, la scala di produzione e la richiesta di garantire sicurezza, qualità e sostenibilità stanno accelerando la necessità di implementare tecniche analitiche rapide e affidabili per la produzione alimentare. La spettroscopia, accoppiata alla chemiometria, porta sempre più allo sviluppo di nuovi metodi per l'analisi di dati complessi e di metodologie analitiche per le applicazioni alimentari. La chemiometria è la disciplina che applica metodi matematici e statistici per estrarre informazioni significative da dati chimici complessi, facilitando l'analisi qualitativa e quantitativa dei sistemi chimici, compresi i bioreattori, i tessuti biologici e l'ambiente. Pertanto, la chemiometria svolge un ruolo fondamentale nell'analisi degli alimenti nell'analisi delle molecole che li costituiscono in quanto fornisce strumenti preziosi per garantire la qualità e la sicurezza dei prodotti alimentari in tutte le fasi della loro produzione. Nel presente studio vengono applicati approcci chemiometrici per analizzare dati biomolecolari, con l'obiettivo di identificare i metaboliti chiave (biomarcatori) associati a diversi stimoli produttivi, come il trattamento termico e il tempo di maturazione dialimenti fermentati. Diversi problemi dell'industria alimentare vengono investigati utilizzando un ampio spettro di tecniche analitiche

Increasing consumer awareness, the production scale, and the demand to ensure safety, quality, and sustainability are accelerating the need for rapid, reliable, and accurate analytical techniques for food products. Spectroscopy, coupled with chemometric techniques, are increasingly leading to the employment of complex data analysis techniques and advanced analytical methodologies for food applications. Chemometrics is the discipline that applies mathematical and statistical methods to extract meaningful information from complex chemical data, facilitating qualitative and quantitative analysis of chemical systems including bioreactors, biological tissues and environment. Therefore, chemometrics plays a pivotal role in food analysis as it provides valuable tools for ensuring the quality and safety of food products throughout their production stages. In the present research study chemometric approaches are applied to investigate complex biomolecular data, aiming to the identification of key metabolites associated with different production stimuli such as thermal treatment and ripening time of fermented food. Diverse problems of food industry are investigated using different analytical techniques.

Roberta Tatti

Tema di ricerca:
Modelli energetici, gestionali, economici ed ambientali per la produzione e l'utilizzo di idrogeno verde su larga scala/ Energy, management, economic and environmental models for the production and use of green hydrogen on a large scale

Abstract:
Le principali tematiche del dottorato riguardano la modellazione, simulazione e ottimizzazione di sistemi di stoccaggio a idrogeno (elettrolizzatore e serbatoi di stoccaggio a bassa ed alta pressione) integrati in microreti rinnovabili (fotovoltaico, batterie di stoccaggio ed altri componenti fondamentali, quale ad esempio il compressore). L'obiettivo principale è quello di studiare e simulare la produzione di idrogeno verde ad elevata pressione che verrà utilizzato per il rifornimento di una flotta di autobus, nel contesto più ampio che prevede la sostituzione di mezzi diesel con mezzi più sostenibili. Diverse strategie di gestione saranno elaborate durante lo studio, al fine di valutare diverse ipotesi di utilizzo dei componenti della microrete con l'intento di trovare i migliori risultati in termini di minor costo di produzione dell'idrogeno, elevata autosufficienza del sistema e minori emissioni possibili.The research project aims to develop systems to produce hydrogen and other energy carriers using renewable energy. The research seeks to design plant configurations and operational strategies for integrating green hydrogen into industrial processes by developing mathematical models, integrating innovative technologies, and optimising the processes. The analyses aim to enhance the sustainability and efficiency of industrial processes in the energy transition.

The main topics of the PhD concern the modeling, simulation and optimization of hydrogen storage systems (electrolyzer and low- and high-pressure storage tanks) integrated in renewable microgrids (photovoltaic, storage batteries and other fundamental components, such as the compressor). The main objective is to study and simulate the production of high-

pressure green hydrogen that will be used for the refueling of a fleet of buses, in the broader context that involves the replacement of diesel vehicles with more sustainable vehicles. Different management strategies will be developed during the study, in order to evaluate different hypotheses of use of the components of the microgrid with the aim of finding the best results in terms of lower hydrogen production cost, high self-sufficiency of the system and lower emissions possible.

XXXVII ciclo

Giulia Casu

Tema di ricerca:
New technologies for the assessment and reduction of biomechanical risks in working environments

Abstract:
Individuals who are frequently exposed to overexertion, non-neutral posture, and repetitive motions during their working activities, are at risk to develop work-related musculoskeletal disorders (MSD). Other than representing a major public health issue with relevant socioeconomic consequences (due to absence from work), MSD can significantly affect workers' performance, as well as their well-being and quality of life. Traditionally, in order to assess the exposure to physical risk factors, observational methods and self-reported surveys have been largely employed. Nevertheless, such approaches are time-consuming, inherently subjective and scarcely applicable in case of activities highly dynamic and not repetitive in nature. However, particularly in the last decade, direct techniques based on wearable inertial sensors have emerged as tool able to partly overcome such limitations. Indeed, the possibility to accurately quantify kinematics aspects of the working activity is likely to improve the traditional exposure assessment of biomechanical risk factors, even though several barriers to their full applicability in actual working environments remain. In fact, aspects involving the type of setup to employ and the lack of a standardized method to interpret the results, still prevent the application of this approach in routine ergonomic assessments. In such context, the first objective of the present study was to propose a simplified set up based on the use of a limited number of inertial sensors to quantitatively evaluate non-neutral posture assumed during actual working task. After validation in the laboratory, performed through comparison with the gold-standard (i.e., optical motion capture system), several applications in actual working contexts to monitor trunk, upper arms and head/neck posture postures of workers employed in construction, logistic and healthcare sectors were carried out. The experimental data were subsequently interpreted based on the risk thresholds proposed by the international technical standards ISO 11226 and UNI EN 1005-4. The obtained results demonstrated that proposed set up is suitable for the quantitative assessment of biomechanical exposure and potentially useful by ergonomics practitioners to identify and, when possible, modify critical aspects of the working process. Nevertheless, different activities, such as those of construction work, require prolonged and forceful exertions that cannot be modify by only re-designing the working process. In these situations, assistive tools such as exoskeletons may result advantageous to support workers by relieving, at least partly, the load acting on specific parts of the body, such as upper arms. Therefore, the second objective of this study was to evaluate benefits and limits of the use of passive upper limb exoskeletons designed for occupational use. Following an extensive campaign of test performed in laboratory setting by simulating common construction activities, it was observed that a device-induced effect on upper arm kinematics and muscle activity exists, especially with the highest levels of

support. Although such variations are likely not to impact workers' ability to perform the job and may actually improve their performance by reducing perceived exertion, further studies are necessary to investigate possible long-term effects and issues associated with the exoskeleton use in real working contexts.

Rayane El Mohtadi

Tema di ricerca:
Investigation into the effect of metal z-pinning on the static and fatigue strength of composite joints, supported by acoustic emission techniques

Abstract:
Carbon fiber reinforced epoxy composites have high specific strength, stiffness and fatigue resistance whilst being durable and corrosion resistant, and these properties make them suitable for light-weight aerospace structures. Despite the many advantages, there are some properties that limit the use of composites in aircraft structures. Carbon-epoxy laminates are susceptible to delamination cracking due to the low strength and toughness properties of the epoxy matrix and the fiber-matrix interface. Delamination cracks can grow under relatively low interlaminar loads resulting in a potential threat to the structural integrity and safety of composite structures.
This PhD project focused on the study of translaminar reinforcement for the improvement of the structural behavior of composite joints. The topic addressed is of great engineering and applicative interest for the efficiency of joints in critical structural components, and is particularly current for the development of design solutions aimed at structural lightening, with the aim of reducing energy consumption and promoting future decarbonization.
The activities carried out mainly concerned the study of the structural performance under static and fatigue loads of joints between adherents in fiber-reinforced composite material obtained by co-curing through autoclave consolidation. In particular, supervised the experimental determination of the elastic and resistance properties of the pre-impregnated material (unidirectional carbon fibers in epoxy resin), the realization of the stepped-lap joints with the insertion of steel z-pins and staples in different configurations, the execution of the static and fatigue tests, and the characterization of the damage modes of the composite joints through direct observations and non-destructive techniques based on acoustic emission.
Acoustic emission (AE) monitoring is employed during the displacement-controlled tensile tests to monitor damage propagation during loading using the Vallen AMSY-5 measurement system, with two piezoelectric sensors being mounted at the laminate surface. Furthermore, machine learning algorithms are integrated to process AE data, enabling the recognition and prediction of failure mechanisms in joints strengthened by z-pinning. Fractographic analyses were performed to observe the nature of damage post-failure.
The results obtained have demonstrated the effectiveness of the selective introduction of translaminar reinforcements in the overlapping area of the joint, which have allowed to obtain increases in the static resistance and of an order of magnitude in the fatigue life of

the joints. The analysis has also allowed to highlight the potential and limits of the different geometric configurations of translaminar reinforcement in the joint area of damage and fracture phenomena in joints strengthened by z-pinning. The superior performances of pinned joints are mainly due to the bridging tractions imposed between the crack faces by z-pins and staples, which delay the growth of the debonding crack.

Francesca Carolina Marcello

Tema di ricerca:
Techno-economic analysis of renewable sources in the new paradigms of the ecological transition

Abstract:
Production of energy from renewable energy sources (RES) is pivotal for the reduction of greenhouse emissions and to address the growing world energy demand. However, the intermittent availability of RES causes fluctuating energy generation. Sustainable energy storage systems (ESSs) coupled with RES play the important roles of mitigating fluctuations, improving reliability, and increasing the share of energy due to the RES unpredictable and intermittent nature. With the increase of RES capacity installed, the world is moving from centralized thermoelectric power plants, able to provide energy to the public grid, to a more decentralized set up with small-scale distributed generation system that is smart, flexible and can be interconnected. This configuration would address two other critical challenges of RES: the localized nature and the low energy density. Therefore, decentralization of power generation and distribution comes with some benefits, such as allowing to decrease power loss on transmission and distribution networks and allowing an island configuration that can guarantee energy supply reliable and secure in remote places that are still heavily dependent on fossil fuels. On the other hand, moving to a decentralized setup would lead to a lot of challenges that need to be addressed such as requiring efficient and big standing reserves and more expensive investments. Moreover, a stand-alone RES would not always be able to provide reliable energy, therefore it might be necessary to integrate different types of RESs supported by suitable storage systems. This research thesis aims to address these challenges developing technical and economic models for managing the energy produced by intermittent renewable energy sources in the context of energy transition and sustainability in a decentralized setup. Specifically, this study focuses on two advanced energy storage systems: mechanical (Adiabatic Compressed Air Energy Storage) and chemical (Green Hydrogen and Ammonia) systems. In the first case, the CAES system is coupled with RES to meet the energy demand of a small city of 10k inhabitants. Moreover, two scenarios are considered: when the system is coupled only with PV (Photovoltaic) power plant or with a wind farm. The operation and performance of the system are analyzed by applying a Genetic Algorithm (GA) as optimization method to maximize the RES energy share. The system is effective in increasing the share of energy especially when coupled with PV plant, with a round-trip efficiency of 67% in both cases. In the second case, green hydrogen and ammonia are studied as part of a hybrid energy storage system of a real micro-grid (MG) that supplies

the energy demand of a research facility. Five scenarios are studied with on-grid and off-grid configurations and analyzing different combinations of RESs and energy storage systems. In this case, a Mixed-Linear Integer Programming (MILP) model is developed with the objective to minimize the overall cost of the grid assuming a planning horizon of one year. This analysis allowed to study the integration of new RESs and ESSs not currently installed in the real MG, such as wind turbines and green ammonia. The combination of different ESSs guarantees short and long-term storage. For both the CAES and the hybrid systems, data from the real energy demand and energy production from RES are considered. Through comprehensive modeling, optimization, simulation and performance assessments, details about the design, operation, scheduling and economic viability are presented.

Manuela Pasella

Tema di ricerca:
Decision Theory for biomedical and industrial applications

Abstract:
This thesis explores the synergy between Decision Theory (DTh) and Machine Learning (ML) through theoretical foundations, methodological approaches, and real-world applications.
Decision-making is a fundamental aspect of human life, influencing choices from everyday routines to critical, high-stakes scenarios. DTh provides a structured mathematical framework for making rational choices under uncertainty, balancing risks and benefits to optimize outcomes. Meanwhile, ML has emerged as a transformative tool across various fields, leveraging data to generate accurate predictions. The integration of DTh and ML enhances decision-making by providing a rigorous foundation for interpreting predictions, defining objectives, and optimizing actions.
The first part of this thesis presents the core principles of DTh and an overview of ML techniques. The second part delves into specific ML models, including Decision Trees and Artificial Neural Networks, examining their structure, training processes, and performance evaluation metrics.
The final part applies these concepts to three case studies in biomedical and industrial domains. The first study develops an ML-based predictive model for assessing Multiple Sclerosis risk in the Sardinian population using demographic and immunogenetic markers. The second investigates an ML approach for predicting inadequate immune responses to COVID-19, supporting early intervention for high-risk patients. The third focuses on Distribution System State Estimation, where ML-generated pseudo-measurements enhance the reliability of smart grids.
By integrating ML with DTh, this research demonstrates how data-driven models can improve decision-making in complex environments such as healthcare and power systems, ultimately contributing to more informed, ethical, and impactful choices.

Roberto Putzu

Tema di ricerca:
Multidisciplinary Optimization of Next-Generation Aero-Engine Fans

Abstract:
The last decade has seen rising concerns over the impact that the global civil aviation market has on climate. The role of sustainability in the modern aeronautics has gained a growing importance, and has been identified as a key challenge facing the aviation industry. Today, sustainability is one of the main agents pushing jet engine manufacturers towards the design of machines that consume less fuel and last longer.
A key factor for achieving these targets is an increased adoption of high-fidelity numerical analyses and optimization methods, in order to effectively approach problems that can be efficiently, rapidly and affordably solved only through advanced mathematics. There is also the urge to deal with different engineering disciplines simultaneously, by formulating and solving multidisciplinary optimization problems, thereby saving time in the early design phases and delivering an improved, optimal product in the successive layout stages.
An important aspect to be considered to improve aero-engine turbomachinery components's life and performances is to control and reduce the secondary flows that develop in their blade passages. Secondary flows reduce the pressure ratio and efficiency of aero-engine compressors, alter their operations at off-design conditions and shorthen the life of downstream components.
The work of this thesis makes use of multidisciplinary optimization and highfidelity numerical CFD simulations, to control and reduce the secondary flows in aero-engine compressors, by using vortex generators. The capabilities of these devices are studied in an open testcase transonic compressor, the NASA Rotor 37, by carrying out an optimization and studying different metrics that measure the secondary flows intensity. Building on the gained knowledge, a single-objective constrained optimization of a vortex generator parameterized with 7 variables is performed on axial compressor representative of a real, modern high-bypass civil aeroengine fan. Different constraints are applied to ensure satisfactory performances. An additional weakly-coupled aero-structural analysis is also performed on the optimal vortex generator to assess its material integrity. A simplified vibrational analysis conducted on a representative downstream component demonstrates important reductions in the forced response, which is one of the primary responsible for the life of compressor blades.

Riccardo Trevisan

Tema di ricerca:
Multidisciplinary Approaches and Tools for Enabling Energy Communities

Abstract:
The global energy transition is driven by the necessity to address climate change and promote sustainable development. The pivotal role of energy in sustaining modern societies

and powering global economies is undergoing a transformation, with mounting pressure to reduce dependence on fossil fuels, which are responsible for considerable climate-altering emissions.

In response to this challenge, a number of international initiatives have been put forth, including the UN 2030 Agenda for Sustainable Development and several non-binding Climate Agreements. These international agreements have urged states to commit to reducing emissions, increasing the use of renewable energy sources, and adopting cleaner and more efficient technologies.

In this global context, the European Union has assumed a pioneering role, proposing ambitious strategies and policies such as the European Green Deal, an action plan that aims to make the EU climate neutral by 2050. The initiatives aimed at achieving this ambitious goal are founded upon principles of equity and sustainability.

At the core of these initiatives are Energy Communities, which represent an emerging model of energy production and management that enables citizens, businesses and local authorities to engage actively in resource management. Energy Communities have the potential to play a pivotal role in the decentralised management of the energy system and serve as catalyst initiatives for the direct and active involvement of local communities in the energy transition, thereby creating new opportunities for sustainable development.