MECHANICAL ENGINEERING / PHYSICS / PRESERVATION OF THE ARCHITECTURAL HERITAGE / STRUCTURAL, SEISMIC AND GEOTECHNICAL ENGINEERING / URBAN PLANNING, DESIGN AND POLICY / AEROSPACE ENGINEERING / ARCHITECTURE, BUILT ENVIRONMENT AND CONSTRUCTION ENGINEERING / ARCHITECTURAL URBAN INTERIOR DESIGN / BIOENGINEERING /DATA ANALYTICS AND DECISION SCIENCES / DESIGN / ELECTRICAL ENGINEERING / ENERGY AND NUCLEAR SCIENCE AND TECHNOLOGY / ENVIRONMENTAL AND INFRASTRUCTURE ENGINEERING / INDUSTRIAL CHEMISTRY AND CHEMICAL ENGINEERING / INFORMATION TECHNOLOGY / MANAGEMENT ENGINEERING / MATERIALS ENGINEERING / MATHEMATICAL MODELS AND METHODS IN ENGINEERING

PhD Yearbook | 2021

DOCTORAL PROGRAM IN ELECTRICAL ENGINEERING

Chair:
Prof. Gabriele D'Antona

The main objective of the PhD Program is to allow a direct, prompt and efficient involvement of PhD graduates in academic and non-academic research and development bodies. A PhD in Electrical Engineering has a solid basic knowledge of applied mathematics and physics. This is essential, particularly for handling and understanding advanced tools and methods as well as for proper modelling, analysis and design of electrical engineering applications, with particular regard to power applications. A PhD in Electrical Engineering well knows methods and applications in the main disciplines of Basic Electric Circuits and Fields, Power Systems, Electrical and Electronic Measurements, Converters, Machines and Electrical Drives.
The most important part of the PhD program is the development of the research that will be the core of the PhD dissertation.

The main research areas are:
A) **Electric Circuits and Fields**: This area is intended to provide the basic knowledge of methods in electrical engineering for power applications. PhD students are specifically trained to develop critical ability and innovative approaches. The training method encourages the development of discussion and debate skills in a team environment.
The main research and training subjects are: Nonlinear networks and periodic time-variant networks; Analysis of three-phase and multiphase systems; Switching circuits; Electromagnetic field equations; Electromagnetic field numerical analysis; Electromagnetic compatibility; Design techniques devoted to electromagnetic compatibility
B) **Power Systems**: A PhD in the field of Power Systems deals with the following subjects: electrical energy production (e.g., frequency and voltage control, protections, renewable energy sources, Dispersed Generation, Microgrids); electrical energy transmission (e.g., power system analysis, real and reactive power optimization, security and stability, integration of renewables); electricity markets (e.g., models, ancillary services, regulations); power quality and Smart Grids (e.g., harmonic distortion, active filters, UPS, interruptions and voltage dips, DC distribution).
C) **Electric machines and drives**: This research field is strictly related to the rising demand for improved machine and converter performance, in terms of low price, efficiency, robustness, dynamic response and drive control. This need leads to device optimization and better design and testing criteria. Moreover, a system approach is required for accurate integration of technical and economic aspects for final application.
The main subjects in this field are: Use of new materials; Novel magnetic structures; Methodologies of model development for design and operating analysis; Optimization procedures; Use of finite elements code, simulation programs and environments for device study; Control system definition both on the device and system side.
D) **Measurements**: This research field concentrates on the fundamentals of metrology, particularly with respect to characterization of modern measurement systems based on complex digital signal processing structures. Some of the main subjects of study are: measurement methodology as it relates to power systems, including medium and high voltage systems and components, as well as both digital and analog signal processing. Methodologies and measurement systems associated with industrial automation and, in particular, microelectronic sensor applications, distributed structures and advanced methods and algorithms for maintenance-oriented diagnosis of complex systems are investigated in detail.

After graduation, PhD are typically employed at:
- Major research centres;
- R&D departments;
- Power generation, transmission and distribution firms;
- Engineering consultant offices;
- Metrology reference institutes and certification laboratories;
- Process and transport automation areas.

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- Leonardo S.p.A.
- Ricerca sul Sistema Energetico - RSE S.p.A.
- Schaffner EMV
- European Commission H2020
- Ministry of Education, University and Research
- Politecnico di Milano

SENSORS FOR MEASURING LEVELS OF AIRCRAFT FUEL

Parisa Esmaili - Supervisor: Michele Norgia

The purpose of this research project is to investigate different methodologies in measuring level of the aircraft fuel and proposing a reliable and cost-effective solution while addressing current challenges in this manner. Here, a differential pressure-based level measurement system which is capable to measure density is developed, characterized and evaluated. A good trade-off between production cost and obtainable accuracy is achieved. To compare with existing capacitive probes, the measurement errors due to density variation and presence of parasitic capacitance, as well as foam have been eliminated. Despite of steady state condition, it shows robust performance under sloshing condition due to turbulences. In addition, improved design of the sensor results into reducing the damage on fuel tank in case of crash while it is still a concern in capacitive probs due to their rigid design.

Probe excitation requires electrical current that can generate a potential explosion in case of crash. Therefore, it is desired to place the excitation outside the tank. Recalling the challenges in this manner such as temperature variation, presence of turbulences and material compatibility, this issue should be addressed too. As a solution, an innovative measurement approach is proposed to measure the level of liquid through the variation of the transmission characteristics of a line, when a part of it is immersed in the liquid. The presence of the liquid slightly changes the local transmission properties, since there is a variation in the capacity per unit of length and the transmission speed of the electromagnetic wave. In contrast with typical TDR system design where the end of cable is open or short circuited, here, line folds and returns to the measurement electronics. This results into very compact design where all electronics are placed outside the tank. Therefore, in addition to the innovative and cost-effective solution, the safety issue regarding prob excitation is addressed.

The PhD thesis describes the research work conducted in Milano (*Optical and Electronic Measurements Laboratory,* Politecnico di Milano) in four chapters following chronological order of the research.

The **first chapter,** titled "*Sensors for measuring level of liquid*" includes introduction to study and investigate possible approaches in a wide range of contact or non/contact as well as direct or indirect methods to detect the level of fuel with high accuracy. Evaluating advantages and disadvantages of each methodology, challenges have been highlighted. In addition to the problem background, the objectives of this research are concluded.

In the **second chapter**, titled "*Differential pressure based liquid level measurement*", a reliable, low cost and accurate liquid level sensor is presented where it is based on piezoresistive differential pressure sensing. To address challenges in present probes associated with dynamic environment, the performance of proposed sensor is evaluated under turbulences and temperature variation. Prototype of the sensor is designed its performance is validated experimentally. In addition to probe contamination, safety issue mainly due to damages in fuel tanks in case of crash because of rigid design of the current fuel probes is addressed by the proposed level sensor. In addition to the piezoresistive pressure sensor, a cost-effective level sensor through capacitive pressure sensor is developed. The performance of the sensor is evaluated under steady state condition while the limits have been addressed.

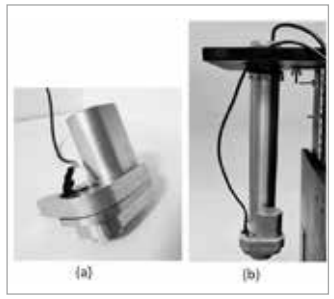

Fig. 1 - (a) The proposed DP-based densitometer as standalone sensor. (b) The proposed densitometer attached to body of Proposed DP-level sensor to measure level and density.

In the **third chapter**, titled "*In-flight densimeter*", a standalone in-flight densimeter is proposed to measure density during flight. Due to recent growing fuel production and presenting alternative fuels such as biofuel, it is desired not only to measure absolute property fluids but also tracking the variation of such properties. In the proposed sensor, the density is measured based on differential pressure sensing principle. The development of a sensor is discussed, and the prototype is presented. Finally, its performance is validated experimentally. The proposed DP-level sensor in addition to in-flight densitometer can address most of the current challenges in fuel quantity probes except probe excitation.

Fig. 2 - The proposed level measurement system based on phase-shift considering different two-conductor waveguides

The **fourth chapter,** titled "*Novel approach in level measurement based on phase shifting*", an innovative measurement system is proposed to detect level through two different determinations, which concern the measurement of overall capacitance of the transmission line and the measurement of indirect time of flight of an electromagnetic radiation. Since both phase shifting measurements provide a result that varies linearly with the liquid level, proposed system has an intrinsic redundancy. Here, measurement method can simultaneously detect both effects, through a compact and low-cost design. The measurements made directly in the baseband without requiring any frequency conversion. The prototype design and system configuration are studied by means of simulation and experimental tests. Several factors are considered to achieve Optimal performance as explained in theoretical discussion and demonstrated experimentally.

NEW METHODS FOR COST/BENEFIT ANALYSIS APPLIED TO THE ELECTRICAL INFRASTRUCTURE FOR THE GENERATION, TRANSMISSION AND DISTRIBUTION

Pierernesto Gatti - Supervisor: Maurizio Delfanti

The study focuses on three main topics: current state of the Electricity Supply Industry, project evaluation and Cost-Benefit Analysis.

In the last thirty years, competition was introduced in Electricity Supply Industry, unbundling the system in more sectors, such as generation, transmission, distribution and retailing, each with specific characteristics, different from the previous vertical integrated system. This process, introducing private players in the system (IPPs, Retailers…), determined the return of profit as an essential goal of the business. Yet, a second fallout of the process is the need for regulations to protect the societal interests, as distribution and transmission segments are natural monopolies.

The coexistence of natural monopolies and competitive players in this industry has raised the challenge to find efficient evaluation methods suitable for decision makers: such methods have been investigated in the existing literature, but there are still some undefined areas, which this work intends to analyse.

Considering the present structure of the system, project evaluation is a necessary tool in today´s electricity supply industry and different methods can be used to match the different stakeholders´ needs. Therefore, the most suitable evaluation tools for a successful governance of the system are analysed, focusing, in particular, on the appropriate coupling between the numerous available evaluation tools and the different sectors. In order to achieve the mentioned objective, the work comprises an initial theoretical section, followed by a more applicative part.

In more detail, the work starts with a review of the current structure of the Electricity Supply Industry through an accurate study of the evolution of the power sector. The focus is on the development of the regulation of natural monopolies in the electricity system, in order to describe the peculiarities of the different sectors and their interactions. Principally, two categories emerge in this industry: regulated and private sectors. Moreover, the recent evolution of the Electricity Supply Industry both in North America and Europe is based on the creation of National Regulatory Authorities and International Bodies and Agencies.

Once identified the characteristics of the sectors, the need for differentiated evaluation methods for the feasibility of projects arises. Thus, the methodologies already in use are scrutinized, together with the decision-making processes of the main international agencies and organizations. The outcome of this analysis is a list of the most common decision-making tools, which can be split into two groups, corresponding to the above-mentioned categories.

After the theoretical analysis of the decision-making tools, they are applied to four case studies: three project appraisals and one evaluation (or peer review). Through this practical application of the Cost-Benefit Analysis and other simpler evaluation tools, observations about the strengths and weaknesses of the different methods are derived.

Some propaedeutic considerations about ESI and its evolution in the last decades are presented, as well as some peculiarities of the electrical system. The work reviews in details project evaluation and selection, financial analysis and its most common tools, and Cost-Benefit Analysis.

After the theoretical part, four case studies are described, which include: life cycles of transformers (costing and capitalization of the losses), risk analysis of a waste treatment plant, and cross border interconnectors. These projects are analysed from the perspectives of a Transmission System Operator and of a National Regulatory Authority.

Utilising the outcomes of the previous points, a definition of the most suitable evaluation tools for each sector in ESI is attempted, with the result of coupling the most appropriate project evaluation methods to the different players. For each segment, the analysis identifies the type of players (i.e. Private Investors, System Operators, National Regulators and Governmental Agencies and International Bodies and Agencies), market type (competitive or regulated), main goal (company profit and / or societal benefit), characteristics and their most common decision-making tools.

ADVANCED MODELLING TECHNIQUES FOR ELECTROMAGNETIC COMPATIBILITY AND SIGNAL INTEGRITY CHARACTERIZATION OF NONUNIFORM MULTICONDUCTOR TRANSMISSION LINES

Xiaokang Liu - Supervisor: Flavia Grassi

Accurate prediction of electromagnetic compatibility (EMC) performance of nonuniform multiconductor transmission lines (NUTLs) is of paramount importance for developing proper mitigation techniques to ensure system operation reliability, and often challenging for EMC engineers from several industrial sectors in terms of precise geometrical modeling and fast solution. The aim of this research is to develop advanced modeling techniques for NUTLs, especially for 1) geometrical modeling and fast solution of hand-assembled bundle harnesses, which are crucial steps to provide essential information about the amount of noise to be expected, and 2) efficient block characterization of NUTLs using a perturbative technique, characterized by both high computational speed and enhanced flexibility.

First, in the dissertation, a new modeling approach to generate wire bundles with geometry accurately mimicking the random displacements of the wires in real, hand-assembled bundles is proposed. To this end, the wire trajectories are modeled by three-dimensional curves that retain continuity of the wire path and its first derivative, allow enforcing random fluctuations of wire position in the bundle cross-section and controlling bundle density. An iterative algorithm involving both local and global perturbation of initially-generated trajectories is used to prevent wire overlapping. As a whole, the proposed modeling approach is able to reproduce (through the use of a limited number of parameters) the main physical properties of real hand-assembled wire bundles. In order to get either deterministic or statistical estimates of the EMC performance, the obtained bundle geometry can be easily imported into 3D electromagnetic solvers or modeled as a Multiconductor Transmission Line (MTL) by approximating the nonuniform wire paths as a sequence of uniform cascaded sections. Application examples aimed at the prediction of crosstalk and field-to-wire coupling are used to prove the importance of accurate modeling of the bundle geometry and proper digitization of the bundle along its length for prediction at high frequencies of the electromagnetic noise induced in the terminal units.

While the first part deals with wire bundles approximately parallel to the ground, the parametric representation of a more generic bundle structure with arbitrary orientation is developed then, and several extensions to the modeling process, e.g., modeling bundles of twisted-wire pairs and interconnecting different bundles, are discussed, allowing for a more realistic characterization of real-world bundles. The generated bundle geometry is used in combination with full-wave and transmission-line based simulation, providing accurate prediction of the noise induced at the bundle terminals due to crosstalk between wires and due to an external electromagnetic field. To this end, a fast, numerical MTL model is developed for predicting the radiated susceptibility of arbitrarily oriented wire bundle structures illuminated by a possibly nonuniform electromagnetic field. The proposed method foresees the modeling of nonuniform MTL via cascading of equivalent uniform MTLs with pertinent lumped sources derived by Agrawal representation and accounting for field-to-wire coupling effects, considering suitable discretization and sampling of the wire bundle geometry as well as the incident electromagnetic field.

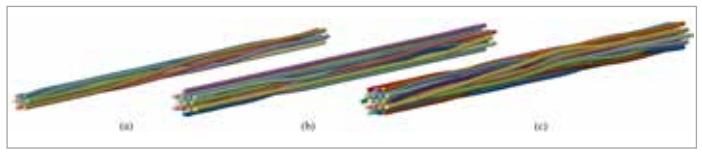

Fig. 1 - Generated random bundle samples via the proposed algorithm with 0.5 m axial length consisting of (a) 7 wires, (b) 13 wires and (c) 19 wires.

In particular, the arbitrary bundle orientation is accounted for by taking into consideration the projection of field onto the bundle direction, and by considering the actual wire lengths inside bundle. The proposed examples proved the validity of the proposed algorithm and the need for accurate representation and discretization of the bundle if reliable predictions in a wide frequency interval are the target, and also highlighted the significantly improved efficiency of the proposed technique compared with full-wave solution.

Also, a novel procedure for the frequency-domain solution of NUTLs is presented. The procedure is based on a recently-proposed perturbative technique, which is proven to be computationally more efficient than standard solution approaches, which are based on line subdivision into uniform cascaded sections (UCS). With respect to the original perturbation technique, the procedure proposed here offers more flexibility, as it provides a representation of the NUTL under analysis in terms of *S*- and/or *T*-parameters at its ports. Moreover, it retains the same prediction accuracy at the price of a slight increase in computational burden, which can be mitigated anyway through parallel-computing. Furthermore, even without *ad hoc* (parallel) implementations, the proposed procedure outperforms other approaches to solve differential lines with partially- or fully-repetitive geometries. Namely, it assures accurate prediction of output quantities with reduced simulation time. This is proven by three application examples, namely two differential trapezoidal tabbed lines (one with interdigital tabs and one with facing tabs) and a differential microstrip line with a varying common-mode (CM) impedance (as such reducing CM noise). Comparison with full-wave simulations allows assessing the prediction accuracy of the proposed procedure. Comparison with the aforementioned transmission-line based solutions allows appreciating the enhanced computational efficiency.

Finally, a systematic procedure to derive equivalent circuit networks accurately reproducing the frequency response of the input impedance of magnetic cores in a broad frequency range is presented. The proposed procedure foresees to represent the effective complex permeability spectra of a magnetic core by a high-order Debye series expansion, which is subsequently synthesized into suitable Foster and Cauer networks. Such networks can be implemented in any circuit simulator, and are particularly favorable for time-domain transient simulation since they can be easily combined with hysteresis models. Two nanocrystalline tape-wound cores and a commercial bulk current injection probe are used as test cases to prove the effectiveness of the proposed method both in terms of accuracy and ease of implementation.

DESIGN OF A HYBRID COMMON MODE EMI FILTER FOR AUTOMOTIVE APPLICATIONS

Enrico Mazzola - Supervisors: Flavia Grassi, Alessandro Amaducci

Directives from governmental bodies, national and international, towards a more sustainable transportation industry set more and more stringent CO2 emission reduction targets.
One of the major steps taken by the original equipment manufacturers (OEMs) is the progressive electrification of vehicles, which, compared to internal combustion engine (ICE) vehicles, brings benefits from many points of view. A better energy efficiency, energy security by reducing the reliance on oil-based fuels, less air pollution issues, especially in urban areas, noise reduction and industrial development are some of the highlights linked to the electric mobility. From a technical point of view, due to the electrification, the automotive industry is facing new challenges, and the electromagnetic compatibility (EMC) is one of the engineering fields that has been affected the most.
While in the past, with ICE vehicles and limited on-board electronics, EMC was a minor issue and mainly related to customer satisfaction, nowadays has become a major topic, related to safety and proper functionality of the vehicle.
EMC standards set both by international committees, e.g., CISPR, IEC, FCC and CEVT, and by OEMs must be fulfilled at component and vehicle level to be able to sell the vehicle and to guarantee the safety and functionality of the car. Due to the increased electromagnetic interference (EMI) sources, an electric vehicle (EV) is a complex problem from the EMC point of view, and EMI filtering has become a must.
Passive filters are the state of the art in the automotive industry, but sometimes this is not enough to achieve the required filtering performance, by using the allowed components, in the given space and within the desired range of price. To achieve an optimum compromise among the aforementioned constrains, active filtering techniques are the most appealing alternatives and must be assessed also in the automotive industry.
The purpose of this research study is to define a modular approach to the design of a hybrid EMI filter, combining active and passive solutions. The research includes a novel measurement technique for switched-mode power supply (SMPS) modal impedances, required in the pre-development phase to take the proper design choices and to model the equivalent modal noise source, a time-frequency analysis of the typical common mode noise and an enhanced circuit model for the derivation of the insertion loss (IL) of an active filter.
All the aforementioned pieces of information have been used to design and prototype a hybrid common mode active filter tuned for 48 V traction inverter application. The electronic circuit design choices, as well as the passive filter elements, have been explained and argued. Eventually, after complete system simulations, the device is tested in a CISPR 25 pre-compliance test setup including the traction inverter and an electric motor, showing excellent attenuation results.
Strengths and limitations of active/hybrid EMI filters are also discussed based on the outcome of the research, and eventually future working directions and improvements to the device built are presented.
This work is to be considered as a proof of concept for active filtering in automotive applications, and it gives a solid starting point for the realization of hybrid filters suitable for 48 V, 400 V and 800 V powertrains.

RENEWABLE ENERGY COMMUNITIES

Matteo Moncecchi - Supervisor: Marco Merlo

When we speak about Energy Communities (ECs) we generally refer to groups of citizens who organize themselves to actively contribute to the energy transition, producing energy and meeting their energy needs through the exploitation of renewable sources. Beyond this, the EU has recently provided formal definitions for the ECs and all the Member States are required to introduce them into their national legislation, ensuring an enabling framework to promote and facilitate their development. These recent innovations have stimulated new interests in methods and models to properly deal with the ECs peculiarities.

ECs are not isolated microgrid; the energy produced is shared among the members of the community using the public infrastructure or also exchanged with other actors on the market. Therefore, self-sufficiency is an important aspect but it is not a technical requirement and it is not mandatory to achieve a complete autarky. On the contrary, the optimal planning and operation of an EC are driven by economical evaluations that take into account both energy exchanges among community members and with the external energy system. This thesis provides some elements to investigate benefits and risks correlated to ECs, evaluating the issue from three different perspectives: the one of the EC as a whole, the one of the EC members (i.e. citizens, municipalities and SMEs that participate to the EC), and the one of the system in which they are hosted (i.e the public distribution network).

The first part of the thesis concerns the definition of a reference framework, that is composed by a legislative framework and a research one. In the legislative framework, the models of ECs defined in the European Directives are presented and analysed. These are the Renewable Energy Community (REC) and the Citizen Energy Community (CEC). Moreover, a detailed description of the Italian scenario is proposed starting from the historical energy cooperatives to the current process of transposition of the European Directives, and the characteristics of the experimental phase currently ongoing in Italy is analysed. The second element of the reference framework focuses on the ECs state of the art in the scientific literature. This clearly shows that the interest in ECs has grown very fast in recent years, but most of the studies are not yet aligned with the new EU definitions. Some classifications of community-based initiatives are reported and a review of the most interesting research projects currently focusing on ECs is provided.

The second part of the thesis deals with methods and models for the analysis of ECs. A model capable to evaluate energy and economical exchanges within a REC is proposed. The peculiarity of the model is the ability to consider separately the self-consumed energy and shared one, to properly evaluate their economic values based on the different tariff structures. The goal of the model is to find the optimal DERs portfolio in terms of installed generators and storage capacity, optimizing the net present value of the EC investment. The proposed model and methodology constitute a tool that supports the EC planning. Then, the issue of benefit distribution among the EC members is addressed. Game theory algorithms are identified as a suitable approach for this purpose. Therefore, some elements from the cooperative and non-cooperative game theory are presented and examples of application in energy sharing situations are considered. The proposed REC model is formalized as a cooperative game, and a two steps distribution rule, based on the Shapley value among clusters of users followed by a proportional allocation, is proposed.

In the cooperative game of the REC, the players are the producers (i.e. the financers of the generation plants) and the consumers. The economical value generated hour by hour depends on the presence and the interaction between load and production, in particular on the quantities of energy produced and shared. The players can decide to take part to the community or not. Both producers and consumers want to take advantage from the participation to the community. The objective of studying this game is to find a stable and fair allocation rule that gives an adequate payoff to the players, so that each one is encouraged to take part to the EC. The methodology is applied to a real-life case study of EC with more than one hundred members based on the Italian scenario.

Finally, changing perspective, the point of view of the distribution system operator is also considered, and the impact that ECs could have on the MV distribution network is tackled. The relationship between distributed generation and EC is discussed and a review of the hosting capacity concept is provided. Then, a methodology based on Monte Carlo simulation is proposed to evaluate the capacity of a network to host new ECs. Two study cases with different characteristics have been built and the procedure is tested on different real-life MV networks. The results shows that the strategy chosen by the EC have a strong impact on the network variables and that the negative impact can be limited if the EC portfolio is optimized for the EC internal self-consumption. The results highlight also the big differences between the rural and the urban context, specifically that in the urban context the energy deficit is higher, therefore there is large space for increasing the self-sufficiency. Nonetheless, to reach high penetration level, the high load density requires the installation of important generation portfolios that can have strong impact on the infrastructure in place. Moreover, in the urban context there is a mismatching between the load density and the scarcity of energy sources, therefore high penetration levels are difficult to reach.

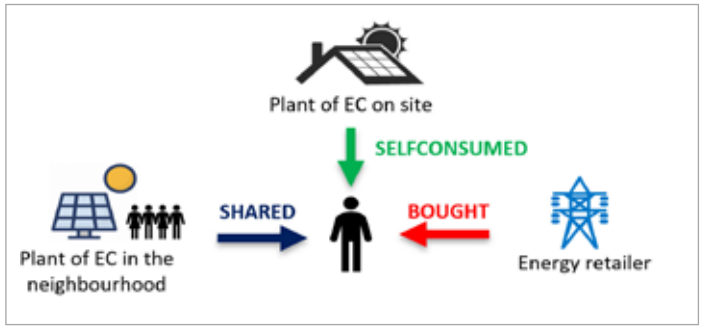

Fig.1 - Possible origin of the energy consumed by the REC's members.

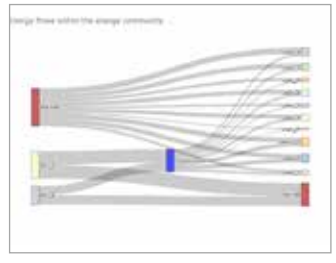

Fig.2 - Example of the energy flows within an EC

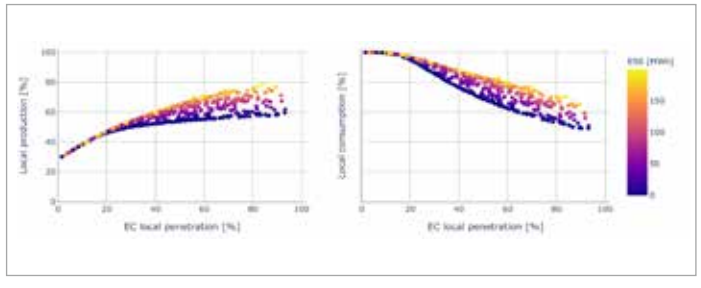

Fig.3 - Example of impact of the ECs penetration on the self-sufficiency of an area

DISTRIBUTION GRIDS EVOLUTION: TOWARDS HYBRID AC/DC AND DC POWER DISTRIBUTION SYSTEMS WITH ISLANDING CAPABILITY

Simone Negri - Supervisor: Enrico Tironi

Electric power systems are experiencing a transition towards sustainable energy, which requires a significant update of system structure and control in order to make the introduction of renewable energy sources an opportunity rather than a challenge.
In this context, the present Thesis is focused on power systems evolution and investigates three aspects in particular. The first aspect of interest is the introduction of innovative functionalities in traditional AC power systems, including islanding capability and hierarchical control structures, in order to take advantage of distributed generation to increase power supply quality and reliability. Successively, hybrid AC/DC power systems are considered, with particular attention to their configuration and to the possible high-frequency disturbances which can affect such a system. Lastly, a perspective on high-performance hybrid power systems based on multiport converters is outlined: converters topology and control are analyzed and their application to distribution system is discussed, with particular attention to system protection and reliability.
The results presented in the following outline interesting development perspectives on the three considered aspects, encouraging further studies. In particular, the solution proposed for AC, hybrid and DC power systems exhibit significant advantages over the standard practice and are technically feasible, excluding regulatory issues.