Institute for Energy Engineering

RESEARCH GROUP OF ENERGY SYSTEMS AND MARKETS

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Instituto Ingeniería Energética

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Research Group of Energy Systems and Markets (e-SYM)

1.1 ABOUT US

The Research Group of Energy Systems and Markets (e-SYM) is one of the founding areas of the University Institute for Research in Energy Engineering (IIE) of the Polytechnic University of Valencia (2001) with more than 20 years of experience in the energy sector.

1.2 ABOUT OUR PURPOSE

We work with determination and commitment to promote new energy saving measures; to improve mechanisms for energy transactions; "manageability" and reliability of energy systems and to contribute to sustainable development. Our activity is currently focused on, but not limited to, the research lines shown in Fig.1. Each of these lines of research and their implications are described below, with special emphasis on activities developed in the last years.

Fig.1 Research lines of the Group of Energy Systems and Markets (e-SYM)

1.3 OUR PARTNERS

Partnership is one of IIE's biggest core values. We collaborate across a diverse ecosystem of partner organizations to drive shared value and innovation. Among our major collaborators and partners there are medium and large prosumers, transmission and distribution network operators, energy traders, research centers, public organizations and equipment manufacturers.

1 SMART GRIDS

1.1 APPLICATIONS TO ELECTRICAL DISTRIBUTION NETWORKS

❖ *Microgrid Planning*

The main objective of this line of research is the study of microgrids, the benefits related to their operation and their particularities, whether working as isolated systems or connected to the power grid. Among the projects carried out in this area, it is worth highlighting the planning of microgrids on the islands of Santa Cruz (Galapagos, Ecuador) or Menorca (Spain), in which distributed renewable resources, demand management and storage systems of diverse nature have been combined to achieve an energy-sustainable island system.

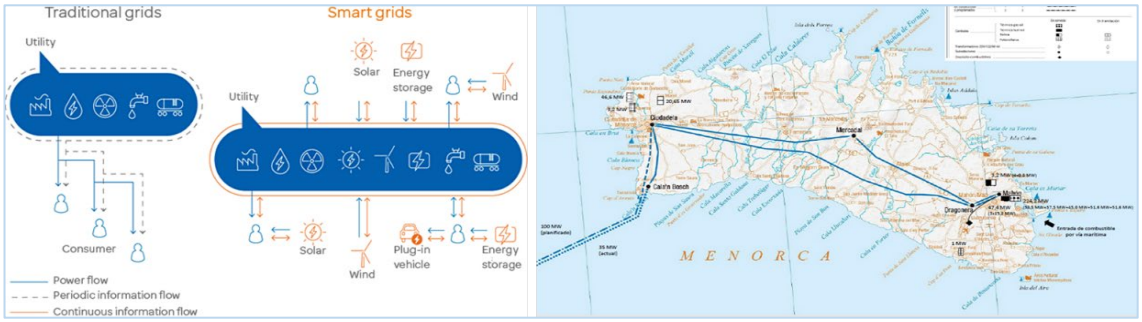

Fig.2 Planning of microgrids in Menorca

❖ *Demand forecasting and network planning*

The activities developed in this area have focused on the design of methods and tools for demand forecasting, the planning of electrical distribution networks and the massive implementation of distributed energy resources, fundamentally renewable generation, using energy management, demand and distributed storage. Likewise, studies have been carried out for the development of virtual generation plants (VPP) to promote the integration of renewable energies into the network. Among the projects carried out, the conceptual design of the smart grid system in Ecuador stands out, carried out for the Ministry of Electricity and Renewable Energy and financed by the Inter-American Development Bank (BID).

1.2 APPLICATIONS IN SMART NATURAL GAS DISTRIBUTION NETWORKS

Natural gas systems, like the rest of the energy systems, are evolving towards a highly technical structure where "smart" devices are called to play a leading role. In this area, the group investigates the characteristics and applicability of communication, monitoring and control technologies in the gas network, especially with a view on converting it into a smart energy network. On the other hand, methods and tools have been developed to analyze the existing barriers in these systems, as well as to evaluate the impact of demand response strategies to solve operation problems in the gas system where these could be applicable. In this sense, these strategies have been applied to gas networks such as that of The Marche in Italy, where potential savings of up to 20% of the annual natural gas bill of industrial consumers have been achieved.

1.3 APPLICATIONS IN DISTRIBUTED HEAT NETWORKS

Distributed heat networks (district heating), especially in northern Europe, are becoming increasingly important in terms of the use of distributed energy, cogeneration and hydrogen contributions. Within this area, new concepts and methodologies are being analyzed for the design of local distributed heat networks. Likewise, different state estimation techniques are being analyzed for the operation of distributed heat networks, as well as the application of storage and demand management techniques. The research carried out in this area has been carried out, since 2019, within the framework of the "Smart Power Hamburg" project, in collaboration with the Hamburg University of Applied Sciences.

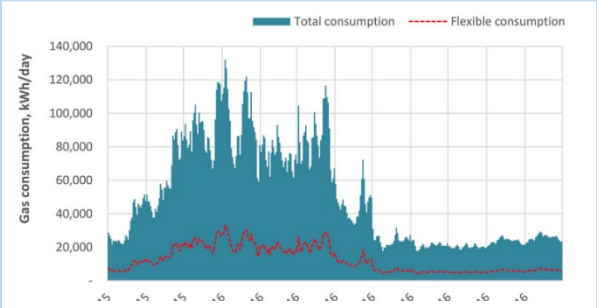

Fig.3 Evaluation of the flexible potential of natural gas in a city in The Marche (Italy)

2 EFFICIENCY AND ENERGY MANAGEMENT

2.1 ENERGY AUDITS

❖ *Comprehensive studies based on processes*

Within this line, the group carries out comprehensive energy studies based on the analysis of energy-consuming processes that take place in commercial and industrial facilities. The objective of these studies is twofold: on the one hand, to obtain a snapshot of the energy use of the facilities and the factors that influence it; and on the other hand, identify, define, evaluate and validate saving measures both from the point of view of efficiency

and energy management, considering technical, economic and environmental aspects. In this area, the group has carried out energy studies in sectors such as public and office buildings, logistics warehouses with and without refrigeration, port infrastructures or different types of industries with intensive use of energy (food, paper, ceramics, etc.).

- ***Design and implementation of dynamic energy indicators in the commercial and industrial sector***

The purpose of this line is to improve the reliability associated with energy indicators that allow dynamic monitoring of the energy performance of the different processes existing in industrial consumers. Along these lines, advanced energy efficiency and management studies have been carried out on different types of industrial and process consumers, such as compressed air production, conservation chambers, air-conditioned working rooms, etc., where the indicators used have been reviewed and new dynamic indicators have been designed, implemented and validated in real industrial settings.

2.2 ENERGY MANAGEMENT SERVICES

The group has developed an online energy management platform through which it is capable of remotely monitoring and controlling any type of electrical installation. This system was developed and implemented at the Campus of Vera of the Polytechnic University of Valencia, achieving annual savings of around 25% of the electricity bill. Likewise, in collaboration with the Power Center for Utility Explorations at the University of South Florida (United States), it was installed in the offices of the Governor of Florida in St. Petersbourg. Currently, the system is being applied to different industrial facilities, verifying savings in the same order of magnitude.

Fig.4 Energy Management Platform

2.3 ANALYSIS OF PRODUCTION, STORAGE AND DISTRIBUTION OF GREEN HYDROGEN AND ITS APPLICATIONS FOR DECARBONIZATION

Nowadays, investments in clean energy sources to meet 2030 renewable hydrogen targets are consistently growing in line with the widespread of decarbonization and reduction of carbon footprint strategies worldwide. Clean hydrogen has been recognized by many institutions and scientists as the green fuel that will boost the 21st century transition towards an effective zero-emission economy.

The European Union needs to accelerate radically the deployment of hydrogen production, import terminal, reconversion, storage, transportation and consumption infrastructure. Public and private investments have resulted in a springing up of multiple international projects, highlighting opportunities and constraints that decarbonization based on hydrogen applications can bring.

New hubs dedicated to hydrogen transportation are going to be implemented but also the injection of hydrogen produced through clean pathways into the existing natural gas pipelines has been tested, resulting as a reliable option for heat and power production with lower emissions than using only natural gas.

The research group focuses its efforts in validating new generation of smart meters for hydrogen using different mixing blending rate value for hydrogen transportation into the existing natural gas pipelines. Moreover, there are studies on going for evaluating the impact of empowering hydrogen for electrical production by means of Demand Response programs. Other studies are focusing on hydrogen synergy with ammonia. Ammonia can play a crucial role as carrier for hydrogen delivery and distribution, as well as an onboard storage medium due to its high hydrogen capacity.

In transportation, E-mobility powered by hydrogen cells is contributing to complete the emission-free portfolio. Sustainability targets for the transport sector are not limited to only road mobility but also ports & terminals are seen as potential cornerstones for the adoption of hydrogen technologies and as backbone infrastructure for hydrogen transportation. The hydrogen adoption as an alternative fuel in the existing ports & terminals for the equipment handling has raised the awareness of hydrogen potential and will facilitate to bridge the existing gaps between research development and industrial application. Our contributions mean to scale up technologies and bring down costs to allow hydrogen to become widely used.

3 DEMAND RESPONSE

3.1 ANALYSIS AND EVALUATION OF THE POTENTIAL FOR FLEXIBILITY OF THE DEMAND OF COMMERCIAL AND INDUSTRIAL CONSUMERS

❖ *Comprehensive studies based on processes*

This line of work focuses on the energy characterization of consumers according to their consumption processes and the study of their flexibility from a technical, economic and environmental point of view. In this sense, procedures have been developed for the evaluation of flexibility in industrial and commercial consumers, as well as tools to simulate their participation in operation markets. Some of these procedures and tools

were validated in the "Demand Response in Industrial Production" project, financed by the European Commission, where a pilot experience was carried out in the facilities of several industrial consumers belonging to the paper sectors, refrigerated logistics warehouses and production of meat products.

3.2 TECHNICAL-ECONOMIC STUDIES OF THE IMPACT OF THE DEMAND RESPONSE ON OPERATIONAL PROCESSES AND MARKETS

The activities in this area are aimed at the integration of industrial, commercial and residential consumers in the provision of ancillary services (frequency and voltage control, capacity reserve, etc.) in a competitive manner with generators who are the only agents

Fig.5 Simulation tool for consumer behaviour (DRIP)

that have traditionally provided this service. Along these lines, the group has developed simulation tools to evaluate the technical, economic and environmental impact of these actions, both on the consumers themselves and on the entire electrical system. Likewise, it has developed a standard for the normalized definition of demand response actions and their comparison with the needs of the System Operator. In this area, several projects carried out in collaboration with Red Eléctrica de España stand out and, more recently, the implementation of a pilot with demand aggregation financed by the Iberdrola Foundation

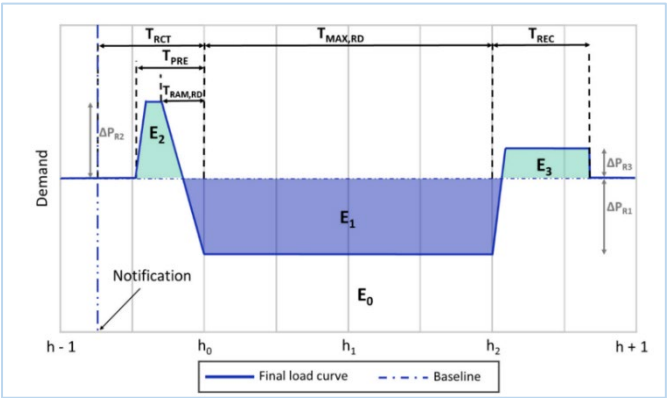

Fig.6 Demand Response actions

3.3 IMPACT OF DEMAND MANAGEMENT IN GAS SYSTEMS

The concept of Demand Response has traditionally been linked exclusively to electrical networks. However, given the similarity between the architecture of the electrical and gas systems, this line analyzes demand response strategies applied to the design, exploitation and management of natural gas supply, transportation and distribution systems. This includes the energy characterization of gas consumers based on processes, the study and evaluation of their flexibility and the design of demand response programs where said flexibility provides value to the managers of the gas system.

4 ELECTRIFICATION

4.1 ELECTRIC MOBILITY IN TRANSPORTATION

Electrification is an emerging economy-wide decarbonization strategy that is beginning to impact the electric power industry.

Fig.7 Ports and Terminals electrification

Fig.8 Turist boat at El Palmar (Valencia)

Our research is focused on the electrification of transportation such as in ports and terminals transportation (STS, RTG, RMG cranes) on road transportation (trucks, cars) and maritime transportation (river boats and vessels). Within this line, work is being done on replacing combustion propulsion systems in boats with electric motors, which involves both the system installed on the boat itself and the associated battery-recharging network. In particular, a pilot boat has been designed to replace the fleet of the Albufera Natural Park of Valencia and the recharging network, which represents significant benefits not only from the point of energy efficiency, but also environmental and social. Some examples are the reduction of noise pollution, the cessation of hydrocarbon discharges or the reduction of emissions in the order of 2 tCO2/year per boat.

4.2 EVALUATION OF THE IMPACT OF THE MASSIVE INTEGRATION OF ELECTRIC VEHICLES (EV) IN POWER TRANSMISSION AND DISTRIBUTION NETWORKS

The objective of this area is to facilitate the massive integration of electric vehicles through the design and necessary reinforcement in electrical networks, guaranteeing stable operation and evaluating the inherent opportunities that this fact represents in the operation of smart networks. In this line of action, among others, the project to evaluate the impact on distribution networks of the massive integration of electric vehicles (cars, commercial fleets, buses, motorcycles, etc.) that has been carried out in Ecuador stands out. The project has been developed according to different scenarios in five representative pilot areas of the country, taking into account different recharge management strategies.

4.3 OPTIMIZATION STRATEGIES FOR THE AGGREGATE MANAGEMENT OF EV CHARGING TO PROMOTE THE INTEGRATION OF RENEWABLES

Proper management of electric vehicle recharging can lead to a series of benefits, including increasing the capacity to integrate renewable energy into electrical systems, in addition to reducing the impact of this new consumption on the electricity distribution grid. In this line of action, optimization algorithms for electric vehicle charging have been developed, respecting the charging preferences of users with different objectives, such as maximizing the economic benefit of the electric vehicle aggregator or increasing the integration capacity of renewable energies in isolated systems.

5 ENERGY MARKETS

5.1 ADVANCED ENERGY MARKET DESIGN (*SMART MARKETS*)

- ***Design and implementation of market mechanisms for the management of Smart Grids***

Smart networks have now become an unprecedented technological laboratory. However, this technological development needs a regulatory and economic framework so that it can be properly exploited. Along these lines, the design of new market structures and mechanisms has been carried out for the integration of new agents linked to smart networks, as well as the design of dynamic rates to encourage the participation of demand.

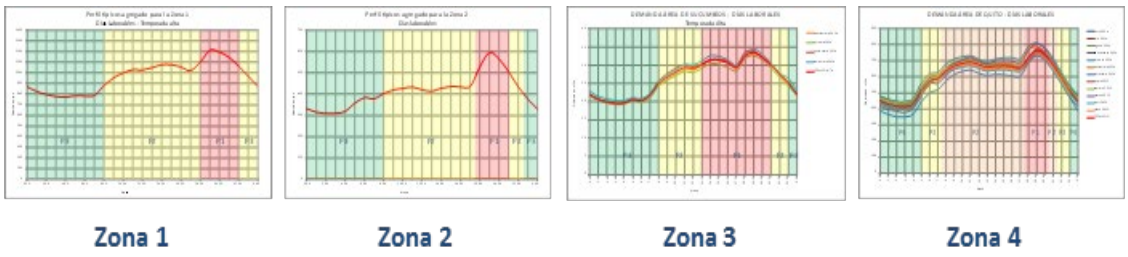

Fig.9 Dynamic rates applicable to the electrical system of Ecuador

❖ *Development of the figure of the demand resource aggregator*

Aggregators fulfill the function of grouping the demand resources of small and medium consumers to provide flexible resources of a significant size for system operators (transmission and distribution) or other system agents that may need this flexibility, such as energy traders, small generators, VPPs, etc. Along these lines, demand forecasting and aggregation tools have been developed and business models have been designed to develop this figure within the electricity and gas markets.

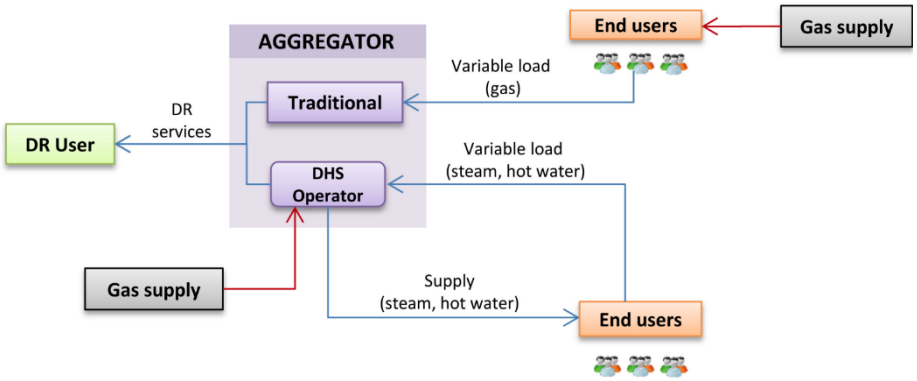

Fig.10 Natural Gas Resource Aggregator Model

❖ *Design of Local Energy Markets (LEMs)*

The technological development of distributed energy resources in recent years has opened the door to new market models where energy resources, whether generation or storage, can be traded between neighboring agents, giving greater prominence to end users. Along these lines, mechanisms are being developed and evaluated, allowing the exchange of nearby energy resources (connected to the same distribution network) so as to avoid incurring costs associated with the use of the transmission network infrastructure.

5.2 RISK MANAGEMENT ASSOCIATED WITH PARTICIPATION IN ENERGY MARKETS AND PRICE PREDICTION

Market participants must have mechanisms in place to protect themselves from price volatility. Some risk hedging tools widely used in other markets, such as financial markets, are derivative products (options, futures, etc.). The work carried out in this line investigates price prediction models, analysis and valuation of electrical energy derivatives to manage the risk of agents when they participate in the market. In this sense, we have collaborated with companies in the energy sector in carrying out risk studies based on price prediction models and the study of different scenarios.

5.3 DESIGN AND EVALUATION OF NEW ENERGY SUPPLIES PROCUREMENT MODELS

The purpose of this line of action is the development of new energy supply contracting models between the energy trader and the consumer within the framework of the existing energy markets that allow the latter to minimize the impact of the energy cost, taking advantage of the opportunities that the markets offer at every moment. In this sense, the evaluation of the optimal contracting of energy supplies for different industrial consumers (automotive sector, food, etc.) and commercial consumers (universities, hospitals, etc.) has been carried out, considering the characterization of the demand and the evaluation of the risks associated with the different forms of contracting available.

5.4. MODELING OF ENERGY DEMAND AND PRICES

Within this line, models based mainly on neural networks have been developed for the prediction of energy demand and prices in wholesale markets. The main objective is to provide consumers and aggregators with tools to negotiate energy supply and optimize their purchase contracts.

The demand models have been developed both at the global level of an electrical system as a whole, as well as for certain commercial and industrial sectors, where work has been done by disaggregating the total demand curve of the installation by processes.

Regarding market prices, the developed models are capable of predicting the results of both short- and long-term (future) markets. In all cases, the prediction errors obtained have been less than 5%.

6 QUALITY OF ELECTRICAL SUPPLY

6.1 IMPROVEMENTS IN THE QUALITY OF SUPPLY IN SMART NETWORKS

❖ *Regulatory proposals to improve the quality of electrical energy*

Along these lines, a comparative study has been carried out of the existing regulations in various reference countries worldwide in relation to the quality of electrical energy, to know the best practices in this field at a global level. This study has served, within the project of smart networks in Ecuador, to carry out a proposal for regulatory changes in said country to achieve continuous improvement in the quality of energy in the electricity sector within the new technological framework of smart networks.

❖ *Development of new reliability indicators*

Taking advantage of the integration of new technological advances in the electricity sector (for example, smart meters), studies have been carried out to improve existing reliability indicators in order to consider the particularities of the operation of smart networks. At the same time, these indicators can reflect more accurately the real situation of each consumer from the point of view of supply quality, especially consumers connected to the low voltage network.

$$SAIFI = \frac{Nº\ total\ de\ interrupciones\ a\ consumidores}{Nº\ \ total\ de\ consumidores\ en\ servicio}$$

$$ENS = \sum_{i=1}^{n} Carga\ de\ consumidores\ afectados \cdot horas\ interrupción$$

$$SAIDI = \frac{Suma\ de\ \ duración\ de\ todas\ las\ interrupciones\ a\ consumidores}{Nº\ \ total\ de\ consumidores\ en\ servicio}$$

$$IKR = \frac{Número\ de\ interrupciones}{Longitud\ total\ de\ las\ líneas\ del\ sistema\ (km)} \cdot 100$$

Fig.11 New reliability indicators

6.2 EVALUATION OF THE PROBLEM ASSOCIATED WITH LACK OF QUALITY IN INDUSTRIAL CONSUMERS

Industrial facilities integrate an increasing number of electronic equipment (variable speed drives, LED lamps, battery chargers, etc.). Therefore, depending on the electrical characteristics of the installation and its percentage of participation in final consumption, they can cause a series of problems associated with the lack of quality of electrical energy, such as reduction in the useful life of transformers, untimely protection trips, etc.

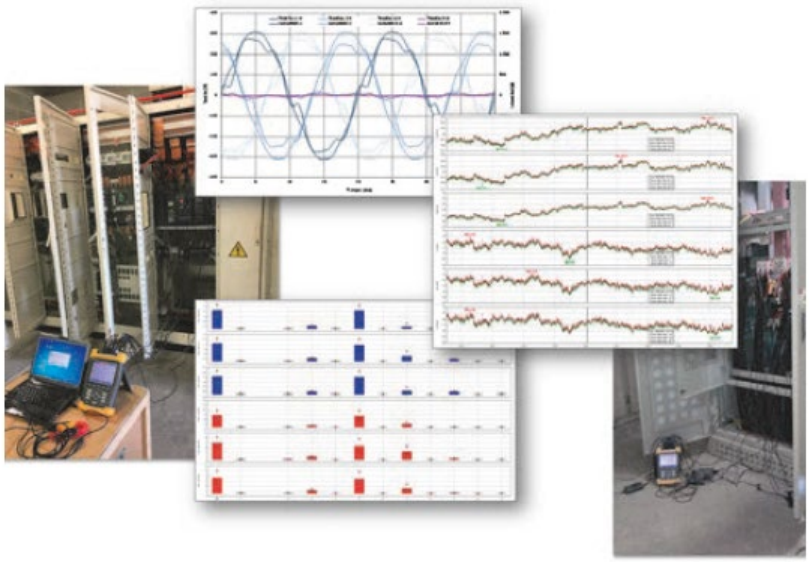

Fig.12 Evaluation of the quality of supply in industrial facilities

In this line of action, a series of quality studies are being carried out on different industrial consumers that are making it possible to detect deficiencies in the operation of the facilities due to the high presence of this type of equipment, as well as to propose, implement and evaluate measures to resolve existing problems and improve network efficiency.

7 TRAINING FOR PROFESSIONALS

The research group offers training courses through which it provides training related to the different lines of research in which it works (Fig.1). These courses are carried out in a very flexible way, adapting to all needs: in-person and online, synchronous and asynchronous, in multiple languages (English, Spanish, Italian). Below are some examples of the latest taught courses but more courses are available on demand.

- PLANNING OF DISTRIBUTION NETWORKS
- SMART NETWORKS AND ELECTROMOBILITY
- TRANSACTIONS IN COMPETITIVE ELECTRICAL MARKETS
- THE IBERIAN ELECTRICITY MARKET
- ENERGY AUDITS AND ENERGY SIDE MANAGEMENT
- NATURAL GAS MARKET AND PRICING
- ENERGY COMMUNITY METHODS AND APPROACHES

Fig.13 Smart Grids and Electromobility Course in Quito (Ecuador)

Fig.14 International conference Sustainability in Maritime sector in Valencia (Spain)

Fig.15 Distribution Network Planning Course in Lima (Peru)

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