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Simulation of Consumers and Markets Towards Real Time Demand Response

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Simulation of consumers and markets towards real time demand response

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Simulation of consumers and markets towards real time demand response

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European Policies Aiming the Penetration of Distributed Energy Resources in the Energy Market

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Abstract

Energy policies have been widely developed in the recent past as sequence of the increasing relevance of distributed energy resources potential in power systems, namely in achieving the reduction of carbon dioxide emissions gaining independence from fossil fuels. Thus, the main factions in the world, as North America and Europe, have been focusing on the implementation of new energy policies capable of managing several types of energy sources considering their decentralized characteristics. In this way, the present work provides an introduction of how the new energy policies, concerning distributed energy resources, are working towards the increase of these resources penetration in the energy mix. Some successful case studies are presented, namely from Europe, to assess the benefits of such policies to consumers, to producers and to energy market as a whole.

Keywords: demand response, distributed generation, energy markets, energy policies, renew-able energy sources, smart grid

1. Introduction

Several countries are facing serious problems with their constant growth, mainly with energy demand and the continuous dependence of fossil fuels usage for energy generation, leading to high CO_2 emissions [*1*], with high impact on the electricity industry [*2*]. Policy makers are promoting Renewable Energy Sources (RES) to decrease the use of harmful fossil fuels in electricity generation.

Currently, one way to counter this problem is the implementation of Distributed Generation (DG). DG relevance has increased since several years ago [*3*] and can be defined as a small-scale and decentralized electricity generation [*4*]. However, this definition is very diverse and ranges from 1 kW photovoltaic (PV) installations, 1 MW engine generators to 1000 MW offshore wind farms [*5*]. This may change between countries, not existing a general policy agreement for this type of technology.

DG allows a considerable reduction in terms of energy losses, since the generation is installed locally, i.e., near the loads. Also, CO_2 emissions are minimized due to the use of RES [*6*] such as wind, PV, small hydro, etc. The increasing of renewable-based DG led to a more complex power system, challenging the way it's planned and operated.

Demand Response (DR) [*7*] programs are being considered to increase reliability and improve energy quality. At economic level, DG presents the advantage of requiring a small investment because of its low production capacity when compared with centralized power plants [*8*].

Although DG presents many advantages, the fact is that their production unpredictability is a major issue for power systems operation planning [*9*], [*10*]. Also, these are small-size resources with low production capacities that aren't able to participate in energy auctions and markets, individually [*11*] – this feature is one of the main barriers of DG implementation. However, it can be surpassed with resources aggregation which enables a considerable sum of power able to participate in wholesale markets. This requires the creation of an entity capable of managing DG and obtain the capacity needed to participate in energy markets, fairly remunerating them for their contribution in case of being able to sell the offered power [*12*]. The activities of an aggregator in wholesale markets are the same as any other large producer, i.e., offering a certain amount of energy for a price per energy unit [*13*].

Other barriers have been encountered in the implementation of DG, covering aspects such as: distribution operator, administrative, economic and tax authorities. Electricity suppliers also have interest in DG, since they recognize that it as a tool that can help covering the demand necessities, creating a liberalized market. The DG allows players in the electricity sector to respond, in a flexible way, to the changes in market conditions. This flexibility is provided due to the fact of DG small-size and commissioning times, when compared to large central power plants. In this way, there's the need to evaluate and analyse the different policies that exist in Europe, in order to overcome the economic and technical issues related with the operations and activities for the management of the retail market. Also, the RES integration potential has to be considered.

In this paper four countries are compared in terms of RES penetration, energy policies and market. The studied countries are: United Kingdom (UK), Germany (DE), France (FR) and Denmark (DK). DG is the main focus of the present work, however, also DR is studied in order to provide an overall view of the integration of distributed energy resources in energy markets. This paper is organized as follows: after this introductory section, section II presents a characterization of DG, section III presents European energy policies, and section IV presents the analysis and discussion of the studied countries.

2. Distributed Energy Resources

The following subchapters 2.1 and 2.2 detail the features of two types of distributed energy resources, namely, distributed generation and demand response.

2.1. Distributed Generation

This section presents a detailed characterization of the common types of resources in DG. There are different types of DG, from the construction and technologic points of view, as shown in Fig. 1 *[14*]. About the DG capacities, these depend on the user type and the respective applications. The most common classifications used are also shown in Fig. 1.

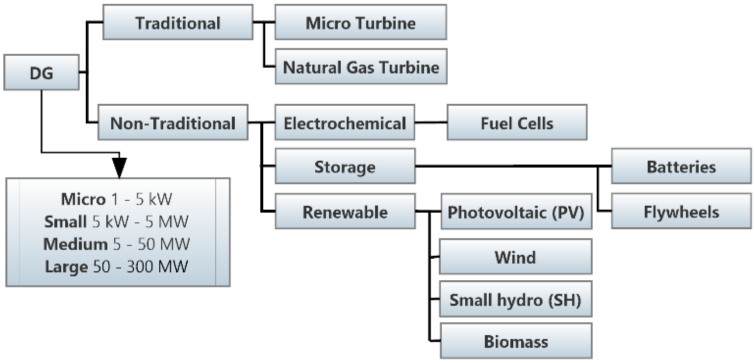

Fig. 1: Distributed generation types, technologies and sizes [*14*].

As mentioned before, DG and DR are not capable of participating in the wholesale market due to their installed capacities and production. Without an aggregator entity able to join these amounts of individual units, DG potential is not fully assessed. In fact, this aggregator concept [*15*] opens way to a new entity, as not just a seller but also as a resources manager and operator [*16*]. Considering the development in energy systems (high interest setting), the DG integration presents itself as a viable solution for a sustainable operation without energy systems dependence on fossil fuels.

In [*16*], an interesting point to DG integration is presented, as several features are pointed from different approaches. For example, from a consumer perspective, the integration of DG in the energy system provides the following advantages:

- receive financial support for installation of renewable technology (prosumer) and profit from energy sale;
- possibility of reducing energy costs due to a more local energy consumption and reduction of network congestion;
- through the use of own production, reduce electricity bill.

The set of EU policies that promote RES *[17*] (significant support implementation as financial instruments, e.g., feed-in-tariffs) drives significant penetration of RES in power generation. Appendix Table 8 [*18*], [*19*], presents the estimated price, in €/MWh produced, for the years 2016, 2020 and 2040. In fact, the share of RES in electricity generation continues to increase, driven by the increasing Emissions Trading System (ETS) prices, along with the continuation of some direct support schemes and of enabling polices, such as streamlined authorization procedures, priority access and the benefits that local population has from investing in local RES.

In Appendix, Table 9 and Table 10 present a prediction for the RES penetration in the network, considering the European countries studied in the present paper [*20*]. The RES share of the various technology types can be seen in Appendix Table 9 for the same regions previously mentioned.

The implementation of these types of technology can be complex since the associated installation costs, considering a domestic appliance, are significant. Initially, several countries in the European context weren't able to have confidence about the success of presenting these types of distributed technologies to its citizens. In this way, to guarantee an initial enthusiasm around the renewable and sustainable concept, promotion strategies had to be adopted by governments. In Europe, these strategies, described in Table 1 [*21*], present different solutions, such as, direct and indirect strategies, where the first causes an immediate interest in RES and the second a more underlined strategy that gradually improves the RES implementation course. According to [*22*], [*23*], the majority of the European countries address the promotion strategies with the use of feed-in tariffs (most used by European countries – 80% of them use this type of scheme – in the year 2010), investment grants, support fiscal measures, green certificates, and tenders. Each of them can be described as:

- **Feed-in tariffs** – feed-in tariffs are widely used in Europe and have become the most successful DG promotion strategy. This tariff enables the priority of renewable energy by applying high energy selling prices to the network. In this way, several advantages are unveiled, such as, a much lower payback time for the investment made. However, the application of this special tariff is limited by a period of time or quantity supplied, and after these goals are achieved the tariff is progressively reduced until a more reasonable one, considering the market conditions. Premium feed-in tariffs grant the seller a superior monetary income since, besides selling the energy in the market, a tariff is applied to the energy obtained from renewable sources, adding a second remuneration to the sale. The major issue with this approach is that usually the energy produced in these terms is mandatory sold to an entity (often the Distribution System Operator - DSO). When there is no need for this energy, overproduction raises as a problem to the entity, possibly causing problems in its operation.

- **Investment grants** – monetary support made by the country's government in order to help the RES interested entities with its implementation. It is important to notice that these investments are only for construction or installation purposes, and are compromised by their economic reliability towards the existing network.

- **Support Fiscal measures** – fiscal support is often used by countries to support potential investors, granting loans with small taxes (small-interest), providing reasonable economic conditions for RES integration. Fiscal measures consist of tax incentives for renewable energy providers and users.

- **Green certificates** – these certificates are a proof of existing share in renewable energy, i.e. the energy producers are obligated to have a certain share of renewable energy in their energy mix, granting therefore a mandatory interest from them in developing RES. Also, the certificates can be shifted between time periods, and can assume several time dimensions (e.g. by hour, day or year). This indicator is very useful, since the certificates define a quota obligation for the producers.

- **Tenders** – tenders can be very useful in an environment with many project developers and companies dedicated to energy supply construction. These contests are presented by the country's government, publishing several renewable energy projects. The better project development proposed by the candidates, wins the tender. However, these propositions have to include features, such as, project location, environment impact, duration, grid connection, project cost, etc. The competition factor is decisive in this kind of promotion, since it helps to develop better solutions and interest in RES. Two types of tenders exist: fixed feed-in tariffs or target-price feed-in tariffs.

Table 1: Promotion strategies [*21*].

		Direct		**Indirect**
		Price-driven	**Quantity-driven**	
Regulatory	Investment focused	-Investment incentives; - Tax credits; - Low interest/ soft loans;	- Tendering system for investment grant;	- Environmental taxes; - Simplification of authorization procedures; - Connection charges, balancing costs;
	Generation based	- Feed-in tariff; - Fixed premium system;	- Tendering system for long term contracts; - Tradable green certificate system;	-
Voluntary	Investment focused	- Shareholder programs; - Contribution programs;	-	- Voluntary agreements;
	Generation based	- Tradable green tariffs;	-	-

2.2. Demand Response

DR can be defined as the modification of the consumer usual consumption patterns in response to price signals, monetary incentives or when the energy system reliability is in risk [15],[24]. The integration of this type of resources has many features, similar to DG (especially at the aggregator level), since it’s also part of DER, but mostly with smaller capacity.

DR besides being load reduction and curtailment, has many other features as load shifting (the load is transferred from a period to another) and energy efficiency (the consumption profile has the same pattern, however its values are lower). In the following bullets and Fig.2 are detailed the programs usually used and with more promising implementations [*7*], [*24*].

- **Direct Load Control** – the utility operator or aggregator has free access to the consumers’ loads, enabling a direct control over the consumption of the load.

- **Interruptible/Curtailable –** the consumer signs a contract were he approves the curtailment or interruption of certain amount of load at a specific time or interval.

• **Demand Bidding –** the consumers can negotiate a price, for curtailing an amount of energy, with utility operator/aggregator.

• **Emergency DR –** consumers can choose to reply or not to emergency signals sent by the operator/aggregator, to reduce.

• **Capacity Market –** the consumer signs a contract where he commits to deliver a certain energy amount when the operator or aggregator are in need.

• **Time-of-use (TOU) –** one of the most used DR programs. It is based on a multi-tariff system that changes the energy tariff according to the hour of the day or the day itself.

• **Real-Time Pricing (RTP) –** the current electricity prices are available in real-time for the consumers, and therefore they can choose or not to reduce load when the prices are high.

• **Critical Peak pricing (CPP) –** the price applied to energy is higher when the network is on peak times or when system reliability is at risk. In this way, the consumers pay more for energy in these periods. This program joins TOU with RTP.

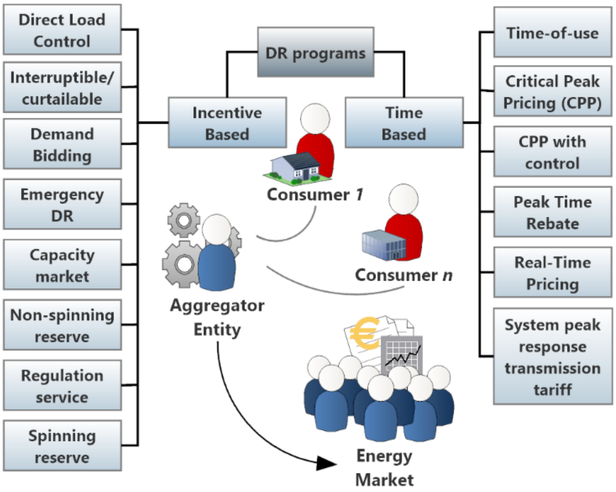

Fig. 2: Demand response programs and context [*24*].

3. European Energy Policies

In this section is presented detailed information about European countries and their energy policies. It is intended to approach the main barriers that these countries face when implementing DG and DR. The countries in analysis face their barriers in distinct ways, as follows.

3.1. United Kingdom

United Kingdom began working towards a greener future in the mid 90's, when renewable energy started to grow. The current legislation that specifies the implementation of RES in the

UK is designated Renewables Obligation (RO).It was introduced for the first time in England, Wales, and Scotland in April 2002, and in Northern Ireland in April 2005 [*25*]. The current obligation amounts to 15% of electricity supply by RES in 2020. The generation by wind source is the dominant RES technology in UK, and the main investors/producers are the major utilities [*26*].

Electricity suppliers with more than 5MW of capacity are supported by a quota system, named Renewables Obligation Orders (ROO) [*27*]. The ROO imposes the obligation on suppliers of electricity, to have an increasing share of their electricity from RES [*26*]. If the suppliers do not have sufficient share of RES, they have to pay a penalty per MWh into a buy-out fund (price adjusted annually with retail price index). In this way, they present the Renewable Obligation Certificates (ROCs). ROC is a certificate issued by a licensed electricity supplier to an accredited generator for eligible renewable energy generated and supplied to customers. This quota system supports plants above 5 MW, although plants between 50 kW and 5 MW are also entitled to choose between the feed-in tariff (FIT) system and the RO [*27*]. Independent RES producers can sell their production directly to traders/suppliers by purchase agreements, or sell in quarterly auctions of the Non-Fossil Purchasing Agency [*28*]. The RES producer sells the generated electricity on the market, since this is supported by the ROCs revenues. The RES have to deal with the uncertainties of two independent markets: forward electricity market and Tradable Green Certificate (TGC) market.

FIT system was announced into law by the 2008 Energy Act and it is more generally used in power plants with a capacity of 50 kW up to 5 MW [*29*]. The energy plants need to undergo an accreditation process, which may differ according to the plant size and source. The electricity exported to the grid by the plant is bought by an electricity supplier, at rates fixed and changed yearly by the Gas and Electricity Markets Authority (Ofgem) [*27*]. This system only applies in England, Scotland and Wales. Fig. 3 presents a summarization of the transactions scheme in the UK energy market.

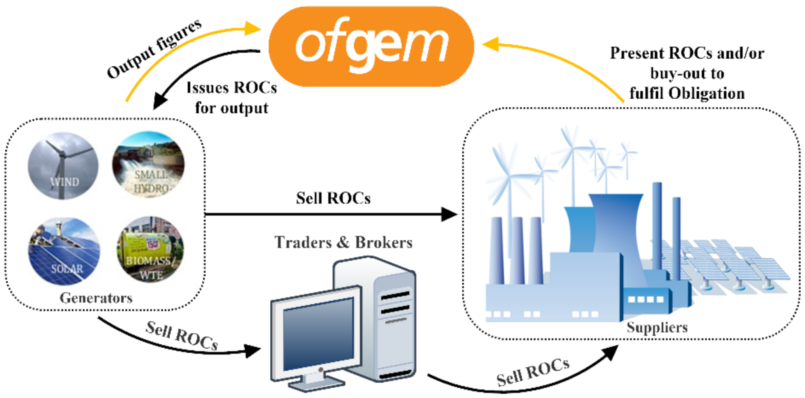

Fig. 3: Energy market scheme [*27*].

A FIT scheme was proposed and implemented with the RO, in order to use the concept of "contracts for difference" (CFD). This scheme was courtesy of the 2013 Energy Act [*30*]. The FIT-CFD is complex, involving the generators being paid the difference between the contract reference price and the electricity market price. The RO is criticized due to this expensive nature, when compared to the German system. This happens because developers have to pay a "risk premium" to investors due to the uncertain income stream under the RO [*31*].

A new form of risk is presented with CFD FIT, where the renewable operators have to trade in UK energy markets. This measure is seen as worst, since only electricity suppliers and large power plants are able to be electricity traders. This means that small producers have to ask the electricity suppliers to give them power purchase agreements, leading to receive no more than 70% of the stated CFD FIT reference price [*32*]. This, when compared with RO seems not so generous, therefore there will be less RES development due to these policies. Currently, this scheme is applicable in England, Wales and Scotland. In Northern Ireland it is expected to be introduced in 2016. From April 2017 the CFD scheme will be the only support scheme for all new RES-E plants exceeding 5 MW [*27*]. In Table 2 some of the subsidiaries schemes are represented for wind, solar photovoltaic and hydro plants.

Table 2: UK subsidiaries summary [*27*].

Type	**Technology**	**Additional Rules**	**Duration**
CFD	Wind	- Onshore (>5 MW) and Offshore	15 years
	Photovoltaic	>5 MW	
	Hydro	>5 and <50 MW	
FIT	Wind	- 50 kW with Microgeneration Certification Scheme - between 50 kW and 5 MW (accreditation based on ROO-FIT)	20 years
	Solar PV		
	Hydro	- accredited by the ROO-FIT	
RO	Wind	- Onshore and offshore wind are eligible under RO scheme - Offshore wind turbines cease to be eligible for ROCs after 20 years from their accreditation date	-
	Solar PV	- Building mounted and ground mounted solar PV are both eligible under RO scheme	
	Hydro	- Eligible, except for large plants (> 20 MW) that were commissioned before 01/04/2002	

According to the current energy policies, in United Kingdom, it is important to point out the need to improve and reform the Electricity Market, the installation of Smart Meters and the development of energy efficiency, while on the other hand, the increase of RES share is supported through feed-in tariffs, CFD system, a certificate system and a quota system in terms of a quota obligation (RO) [*33*].

Recently, UK policy-makers opened a discussion about the necessary regulatory changes required to accommodate the use of DR in their markets. Currently, the DR schemes used are: Short Term Operating Reserve (STOR), Firm Frequency Response (FFR) and the Frequency Control by Demand Management (FCDM) [*34*]. A STOR participant offers its load as reserve to the UK network during pre-determinate periods.

In this period the STOR participant must be available to start-up their generators or reduce the load by the agreed amount, when requested by the grid operator [*35*]. The FFR is an alternative approach to grid balancing. The UK network has a license obligation to control frequency within the specified limits, where the use of FFR with a monitoring software system, operating with a range of equipment such as UPS, generators, pumping systems, air conditioning and others, turning them into smart units which can react instantaneously to changes in demand [*36*]. The FCDM is a rapid-response service used to help maintain system frequency in the specified limits. An unexpected increase in demand or a generation plant outage, can cause system frequency to fluctuate and drop below the desired. The FCDM providers are contracted to respond automatically in these situations to help restore the system frequency to within the acceptable range, by instantaneously reducing load from their processes [*37*].

3.2. Germany

Germany's electricity market has a decentralized structure with a large number of private and public owned utilities [*38*]. The biggest difference of the German electricity system, when compared with many other countries, is the fact that there isn't a single system operator or a separate energy regulator. The four big utilities that dominate the electricity market are: RWE AG, E.ON Energy AG, Vattenfall Europe AG and EnBW AG [*38*]. These utilities are involved in the generation and supply activities. Their development is a response to the closure of 8 nuclear plants and the expansion of RES. Germany has the ambition by 2020 to phase out nuclear energy and have a system that has a share of at least 80% renewable by 2050. The federal Government's energy policies are based on the 2010 "Energy Concept", and the 2011 "Transformations of the Energy System". The first one, is looking for the implementation of a reliable, affordable and environmentalist energy supply system by 2050 [*39*]. The second one, focuses in the increase of renewable generation and complete exclusion of nuclear plants.

In terms of installed capacity, as one can see in Table 3, the share of generation using RES, accounts to 44% of total installed capacity, and is expected to exceed its national 2020 target, regarding the shares of RES in gross final energy consumption, set at 18% [*20*]. Wind and PV are those with the highest share in DG. In PV, the majority (about 65%) is connected to low voltage (LV), 35% are connected to medium voltage (MV) and only few plants are connected to high voltage (HV). In the case of wind, the overwhelming majority (about 95%) are connected to MV [*40*]. Concerning ownership, more than 50% of DG belongs to customers, such as private owners, industrial companies and farmers [*3*]. Fig. 4 presents the RES installed capacity by technology type, over the next years.

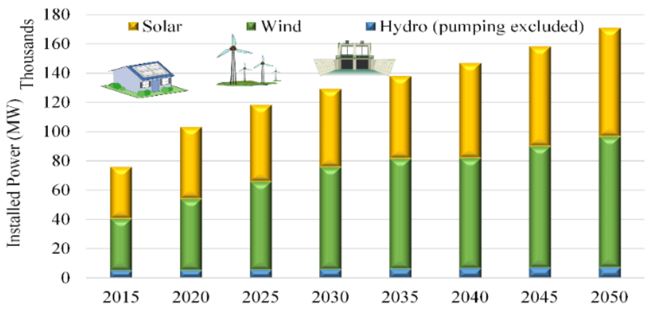

Fig. 4: RES installed capacity [*20*].

Germany was one of the first countries in Europe to implement the feed-in tariff scheme – since 1991. In this first scheme, only one single tariff was applied for all RES technologies. The introduction of the "Erneuerbare-Energien-Gesetz" (EEG), portraying a German Renewable Energy Act, in the year 2000, is a key element in the success of RES expansion. With EEG legislation, a priority and normal feed-in tariffs for each type of RES were guaranteed for a fixed period of time. For most technologies, this period corresponds to a total of 20 years. It is important to refer that tariffs for a new installation are decreased every year by a certain percentage in anticipation of technological learning. In 2009, the German government considered the introduction of a feed-in premium option in parallel to the fixed tariff scheme.

In addition, several modifications were made in this EEG in the last years. For example, generators with an installed capacity of at least 500 kW, that operate new plants, are required to sell their electricity in the energy market – thus the option of feed-in tariff is not applicable (however some exceptions may apply). Other example, is that from 2017 onwards, a tendering process will be implemented and will replace both the feed-in tariff and the market premium.

The tariffs are paid to RES by the DSO, whose grid the RES plant is physically connected, but sometimes, mainly in large wind parks, the connection and sell is made directly to the Transmission System Operator (TSO). The additional costs (price difference between feed-in tariffs and market prices) are passed from the operators through the electricity suppliers to the consumers. RES plants in Germany can be connected to the grid, but the network operator is allowed to curtail the output of these plants, if the network is already congested with the electricity for others plants. Newly installed plants need to be equipped with technical provisions for such curtailment. For example, in DGs new installations with capacity over 100 kW it's required the installation of control and communication equipment. In the case of PV, with a capacity between 30 kW and 100 kW, the owner can decide between installing the control and communication equipment that allows the reduction of generation output remotely, or be limited to 70% of their maximum effective exported capacity. Table 3 presents Germany's subsidies summary for RES [*41*].

Table 3: Germany subsidiaries summary [*41*].

<table>
<tr><th>Technology</th><th>Additional Rules</th><th>Duration</th></tr>
<tr><td>Wind</td><td rowspan="4">- Plant operators can chose monthly between adopting a FIT or a premium scheme
- Regarding FIT, the plant's capacity must be between a power range of 100 to 500 kW
- The Premium scheme for PV installation is only applied to a maximum of 10 MW capacity
- In Premium scheme, the plant operator can sell his electricity directly to a third party or stock market, allowing also the right to premium</td><td rowspan="4">20 years</td></tr>
<tr><td>Photovoltaic</td></tr>
<tr><td>Hydro</td></tr>
<tr><td>Others</td></tr>
</table>

In terms of DR, since 2012, Germany uses it, however only as interruptible loads in the industrial sector. The loads with this possibility are major consumption units connected at least at 110 kV network voltage levels. The TSO can then interrupt 2 types of loads: the immediately interruptible loads (SOL) and the quickly interruptible loads (SNL). The main difference between these two types of loads is reflected in the fact that the SOL loads, are dispatched within a second of frequency deviation, while SNL is activated within 15 minutes. The interruptible loads have a minimum tender quantity of 50 MW and a maximum of 200 MW with the following three availability options: (i) at least four times a week, several times a day for at least 15 minutes at a time, for a duration of up to one hour per day; (ii) once every seven days, be available continuously for at least four hours at any given time; (iii) once every 14 days, continuously for at least eight hours at any given time. The participants can earn up to 2500 €/month.MW of reduced load.

3.3. France

In this subsection, it is presented the energy policies applied in France. They can be completely different from the other countries, since France became highly dependent on nuclear energy after 1974, when the first oil crisis occurred. Nuclear technology allowed France to gain economic strength and huge capacity for demand supply. In 2015, France presents a total of 58 nuclear reactors plus another one under construction, operated by "Électricité de France" (EDF).

Nuclear energy is responsible for supplying about 76% of the country's electricity demand, as one can see in Fig. 5. The high capacity and low cost of nuclear energy makes France one of the largest energy exporters in the world. Despite the highly amount of nuclear energy generation, France is compromised to reduce their share from 75% to 50%, till the year of 2025 [*42*]. The share of RES for electricity generation are currently promoted by feed-in tariffs, tax benefits and tenders [*43*]. According to the information presented before, in the 1990s were implemented tendering systems for power plants with capacity higher than 12 MW.

A few years later, in 2002, the FIT emerged and were applied to power plants with capacity lower than 12 MW. EDF has the obligation to support onshore wind farms, geothermal and biomaterial power plants for 15 years, while offshore wind, hydro and solar power must be ensured for 20 years. On the other hand, the measures applied to the tax benefit allowed a 15% reduction of the investment cost for a maximum of 3000€ a person and a decrease of 7% in VAT, in 2011, over the purchased renewable equipment [*21*], [*44*]–[*47*].

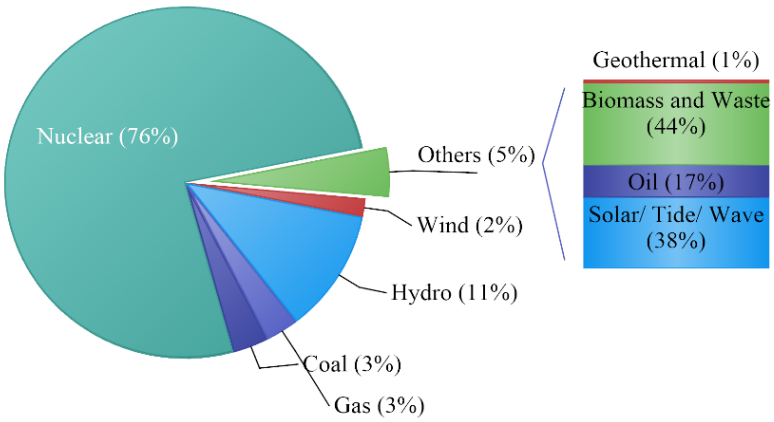

Fig. 5: Electricity generation in France, 2014 [*48*].

The Table 4 intends to schematize the existing subsidies applied to each type generation, in France.

Table 4: France subsidiaries summary [*47*].

Resource	Duration	Subsidies:
Wind (Onshore)	15 years	- 0.082 €/kWh for first 10 years - Between 0.028 €/kWh and 0.082 €/kWh for the next 5 years depending on location
Wind (Offshore)	20 years	- 0.13 €/kWh for 10 years - Between 0.03 and 0.13 €/kWh for the next 10 years depending on location
Solar		- Ground Based: 0.12 €/kWh
		- Simplified Building-Integrated: 0.3035 €/kWh or 0.2885 €/kWh
		- Building-Integrated - 0.46, 0.40, 0.4025 or 0.352 €/kWh, according to the capacity of the power plant
Hydro		- 0.0607 €/kWh plus bonus between 0.005 €/kWh and 0.025 €/kWh for small power plants - Extra 0.0168 €/kWh for energy generated during winter season

France intends to assume a new identity in energy generation, aiming to reach a share of 50% in renewable energy till the year of 2020, since in 2011 RES represented 13.1% of France's electricity production. Some political measures about the growth and development of renewable energy were discussed and adopted in 22nd of July of 2015, in the French Parliament. These policies will lead to the creation of jobs and work towards the energy independence, avoiding the import of fossil fuels by maintaining the energy sector balanced and giving the opportunity for intern companies to enter international markets.

This law also aims new key objectives, such as: a unique authorization for development and installation of wind farms, hydroelectric and biomass power plants, the promotion and encouragement to apply renewable energy in buildings or even the exemption of taxes related to the consumption of bioenergy in the internal market. It is then expected that the RES in 2030 will be responsible for supplying 32% of energy consumption [*49*]. Although France still maintain its dependence on nuclear energy, this already shows results of applying DR programs. In the present year, France's TSO proclaimed an increase by 300% in the total DR contracted capacity, when compared to the previous year, 2014 [*50*]. There are two main time-based programs implemented in France, TOU and CPP (this last one is also known as *Tempo* tariff) [*51*], [*52*]. More detailed information in [*53*].

3.4. Denmark

Denmark has become a European reference in what concerns energy policies and sustainable growing. Since the 1970s, the country has adopted new perspectives in energy use and generation, passing from almost total dependence in fossil fuels (>90%) to self-sufficient (one of the countries, in the EU28, with lowest energy dependence). Their policies establish an estimated goal of 100 percent renewable sources share by the year of 2050 [*54*], [*55*] – Fig. 6. The Danish Energy Agency (DNA), since the 70s, has been gradually increasing the taxes on electricity use, mainly to promote energy savings (energy education) amongst the consumers, gathering at the same time, budget for the energy network research and development. Although this policy is aggressive, it still achieves its creation goals quite successfully.

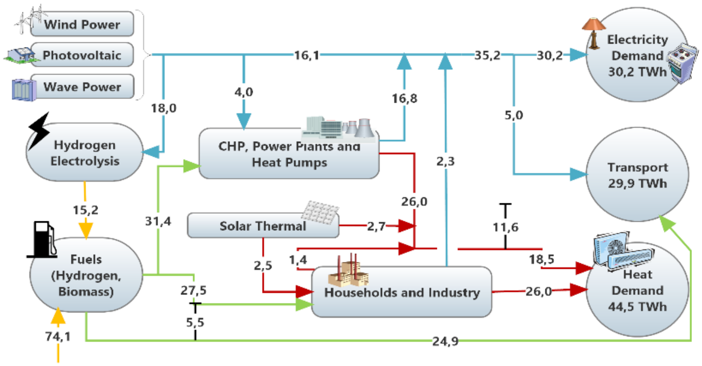

Fig. 6: Denmark 2050 scenario, adapted from [*46*].

In fact, the Danish consumers' electricity prices are within the highest of the EU. The electricity prices, without taxes, is below EU average. In this way, household consumers pay three times more for electricity than industrial consumers [*45*]. Denmark embraced the retail market liberalization in 2003, being possible to consumers the choice of continuing with regulated market prices or change to the liberalized market. However, by the end of 2015, most of the consumers have to adopt liberalized prices since regulated ones are to be removed.

After the market liberalization, the energy sector became in an overall stationary state, not occurring much progress until 2008, when the Energy Policy Statement was introduced. According to [*56*], three critical features for green energy were defined: efficiency, renewable and resources integration. Energy efficient becomes important when a sustainable energy use is required. In fact, several actions were implemented to improve the global efficiency of Denmark, such as, energy labelling and certification of buildings and appliances.

In Denmark, renewable energy integration is performed using several kinds of promotion strategies, such as fixed feed-in tariffs, feed-in premium tariffs, tenders, and tax benefits [*21*]. Such is the case of offshore wind farms, where their construction and implementation is approved by a tender, and afterwards a feed-in premium tariff is applied to the energy produced. Other DG resources are paid by a fixed feed-in tariff. These promotion strategies are implemented during 10 to 20 years, depending on the technology and scheme. For wind energy, the first 3000 monetary units of income are free of taxes [*21*]. This allows a much quicker payback time for the investment made, besides adding competition between investors for the development and use of renewable sources.

Renewable energy may not always be the most trustworthy due to the unpredictability. However, Denmark has been gradually developing its central and long-term planning in order to better predict the energy produced by their renewable sources, mainly wind as the one with more potential. In the actual operation, the DNA provides the following keys to Denmark success with DG and fluctuating renewable sources integration:

- Integration of small CHP units – the system allows a control over heat and electricity, enabling heat storage;

- Existing thermal power plants were updated in order to allow more flexibility in reasonable time.

The connection of DG to the network is performed in two ways [*9*] – DG onshore (e.g. CHP, wind, photovoltaic, biomass and others) is connected to the distribution network, while large wind farms located offshore, are connected to the transmission network. Due to this large use of the distribution network, Denmark has 77 DSOs and only one TSO, “Energinet” (created in 2005 for gas and electricity) [*9*]; it is important to refer that the energy system is divided into two areas, Eastern and Western Denmark (DK1 and DK2, respectively). More recently, Denmark has been focusing its research on the development of hydrogen-related technologies to apply in transportation and energy storage sector [*57*]. In this way, the country can reduce even further their dependence on fossil fuels for huge consumption sectors like transportation and heat supply.

Although Denmark is well advanced in DG implementation, the scenario for integration of DR is not so developed. The cause is not cultural as one may assume, since statistics tell in fact the opposite [*58*]. They show that the Danish people are more aware of environmental issues than other countries, embracing more naturally the use of renewable sources (existing solar panels are mostly consumer-owned) and adopting an energy efficiency posture. So the problem of integrating active consumers in the network and resources management is not because of the consumer itself, but due to technical, commercial and security issues for the operators. In Table 5 some of the subsidiaries schemes are represented for wind and solar energy. The Danish monetary unit is DKK/kWh. More information can be obtained in [*63*].

Table 5: Danish subsidiaries summary [*63*].

Resource	Duration	Tariff (m.u.)	Additional Rules
Wind (Onshore)	6 600 full load hours	0.25	- 0.01 m.u decrease by each point the market price exceeds 0.33 m.u. - 0.023 m.u. for balancing costs
Wind (Offshore)	22 000 full load hours	0.25	- 0.023 m.u. for balancing costs
Wind Tenders [a]	20 years	0.518 0.629 1.051	- Until 10 TWh - Until 10 TWh - Until 20 TWh
Household Turbines	10 years	2.50	≤ 25 kW
		1.30	≤ 6 kW - Annual decrease of 0.14 m.u., during the first 4 years
Solar	10 years	1.30	≤ 400 kW - Annual decrease of 0.14 m.u., during the first 4 years
	20 years	0.60/ 0.40	> 400 kW - First price for the first 10 years, and second price for the remaining years
	10 years	1.45	- Collective - Annual decrease of 0.17 during the first 4 years

[a] Three different regions are considered: Horns Rev 2, Rodsand 2 and Anholt

In Denmark, the generation is negotiated directly in the wholesale market, however when dealing with even smaller amounts (as the case of consumer reductions). The problem becomes more complex, mainly for the system operator that now would have to consider aggregation models for consumers and communicate with the grid company responsible of supplying consumers and dealing with producers [*59*]. Also, the wholesale market makes sense when having a known load to supply, taking into account a certain forecast error. With DR, one has to consider the considerable increase of forecast error, making more difficult for the system operator to balance its network. These are serious issues that slow down the implementation of DR in Denmark, as well as in other countries. Denmark has ongoing projects for DR, such as, Bornholm [*60*]–[*62*]. In order to support DR programs, the existing meters began to be replaced by smart meters in 2010/2011 achieving, four years later, more than 50% of the population.

4. Analysis & Discussion

According to the information analysed and presented along this paper, it is possible to refer that the major countries in European Union (EU) are making efforts to reach 2020 energy and climate outlined objectives. It is important to continually redefine new objectives, in order to achieve the development of energy policies and implementation of DG and DR, aiming the reduction of fossil fuels dependency. The need to implement DG is somehow different and innovative from country to country, since it depends, mainly, from the economic power of each one of them. However, they still have to fulfil the established policy goals of EU.

The present paper allows to understand how four EU countries are working towards the implementation of renewable energy, according to the actual energy policies. As seen, United Kingdom major renewable source is wind, seeking to achieve 15% of RES electricity supply by 2020. Nowadays, DR is being developed to be used in electricity markets, through the existing models, such as: STOR, FFR and FCDM. France is considered DR European leader, once it presents practical results and an increase of their clients year after year. However, in opposite, they are dependent of their high percentage of nuclear energy generation. Currently, France is aiming new policies to incentive the implementation of RES. Germany seeks to extinguish the nuclear energy of their energy programs and expects the RES energy consumption to exceed the value established, previously, in 18% by 2020. The best scenario is presented by Denmark, which is a country well known for their wind farms high generation, leading to a country with almost null dependency on fossil fuels, aiming to higher energy policies, as the case of 100 % RES by 2050.

In Table 6 and Table 7, it is presented the summary of the subsidiaries schemes studied through the analysis of the four countries considered. Also, the references for related information about each of the countries is represented, in what concerns DG and DR.

One can see that Europe is much more committed to DG than to DR, mostly due to the advanced producers' remuneration schemes and to the new energy policies imposed the EU. In what concerns DG, the schemes adopted are, in their majority, homogenous between countries, namely, the adoption of feed-in tariffs. In what concerns DR, the programs are very distinct or are applied to different types of consumers. Therefore, DR isn't yet a usually implemented resource, since Europe seems to still be experimenting the integration of this type of technology in their energy systems (mostly in small networks). This work presents a study about distributed energy resources, energy policies and electricity markets implemented in some EU countries, aiming at new challenges and strategies to a better energy use. Lastly, it is expected the EU to proceed with the improvement and establishment of new climate and energy policies, aiming to reduce CO_2 emissions, and to incentive and implement a higher share of RES.

Table 6: Promotion strategies summary.

Country	Distributed Generation (DG)		Demand Response (DR)	
United Kingdom	• Renewables Obligation (quota system) • Contracts for difference feed-in tariff • Fixed Feed-in tariffs	[21]–[23], [25]–[27], [29]–[32], [53], [64]	• Short Term Operating Reserve • Firm Frequency Response • Frequency Control by Demand Management	[24], [34]–[36], [60]
Germany	• Feed-in premium • Fixed Feed-in tariff scheme	[9], [13], [21]–[23], [26], [31], [32], [38], [39], [41], [43], [64]	• Interruptible loads in the industrial sector • Immediately interruptible loads • Quickly interruptible loads	[7], [13], [60]
France	• Fixed Feed-in tariffs • Tax benefits • Tenders	[13], [21]–[23], [43]–[47], [53], [64]	• Time-of-Use: Green Tariffs • Critical Peak Pricing Tariff called Tempo	[13], [50], [60], [51], [52]
Denmark	• Fixed Feed-in tariffs • Feed-in premium tariffs • Tenders • Tax benefits	[9], [21], [22], [45], [56], [63], [64]	• Ongoing projects, such as, Bornholm • Eco-design buildings and energy labelling to appliances • Frequency Control by Demand Management	[7], [55], [59], [60]

Table 7: Promotion strategies description.

Country	Feed-in tariffs	Premium tariff	Tenders	Tax benefits	Quota System
United Kingdom	• FIT since 2008, to all RES • CFD applied in 2013, subject to capacity	-	-	-	• Introduced in April 2002
Germany	• Used since 1991 with a single tariff for all RES • In 2000, EEG introduced a FIT system for each type of RES	• In 2009, this scheme was introduced by EEG	• This scheme intends to replace FIT and premium, by 2017	-	-
France	• Used since 2002, FIT are applied to RES (wind, hydro and solar)	-	• Introduced in 1990s, tenders were applied to power plants (except wind)	• In 2005, was implemented reduced VAT rate applied to renewable energy services, equipment and delivery	-

Denmark	• Used since 1993 for all RES • In 1999, this scheme was to be replaced by TGC • In 2004, the feed-in tariff was abandoned for wind energy	• By 2003, all wind generators were under this policy	• In 2009, tenders were introduced, only for offshore wind farms	• Were introduced in 1986, to Danish power generation families – removed in 1988 • Wind farms refund in 1993	-

Appendix

Table 8: Estimated level average generation costs [*18*], [*19*].

Resource	2016 (€/MWh)	2020 (€/MWh)	2040 (€/MWh)
Biomass	102.20	88.53	82.36
Wind	87.22	64.83	66.15
Solar PV	191.51	110.37	103.33
Hydro	82.11	73.55	79.19
Geothermal	90.55	42.10	53.55

Table 9: Renewable energy penetration [*20*].

Country	RES Penetration (%)				
	2015	2020	2030	2040	2050
UK	16.00	42.42	50.76	51.61	52.37
DE	44.90	53.53	61.33	63.69	66.20
FR	28.78	38.40	51.29	54.83	54.78
DK	34.05	45.29	57.59	61.58	59.55

Table 10: Renewable sources penetration [*20*].

Country	Type	RES Penetration (%)				
		2015	2020	2030	2040	2050
UK	SH	10.4	3.4	2.6	2.2	2.2
	Wind	77.6	82.1	80.8	83.4	82.3
	PV	10.1	12.7	14.1	12.3	11.2
	Others	2.0	1.8	2.5	2.2	4.3
DE	SH	6.5	5.0	4.4	4.4	4.2
	Wind	46.9	47.4	54.1	51.4	52.3
	PV	46.6	47.5	41.4	44.2	43.5
	Others	0.0	0.0	0.0	0.0	0.0
FR	SH	58.5	38.8	26.0	23.9	21.6
	Wind	28.1	46.9	56.5	52.2	54.9
	PV	12.7	13.6	16.6	23.1	22.4
	Others	0.7	0.7	0.9	0.8	1.1
DK	SH	0.3	0.2	0.1	0.1	0.1
	Wind	93.8	94.1	90.5	91.6	92.9
	PV	5.9	5.7	9.3	8.3	7.0
	Others	0.0	0.0	0.0	0.0	0.0

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Simulation of consumers and markets towards real time demand response
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Hybrid system to analyze user's behavior

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Abstract

The context-aware systems allow the adaptation of the environment, which depends on the values perceived by sensors and on the users' preferences detected from user's behavior. These systems need to adapt at the users' preferences change so as to generate dynamic systems that improve their models while they are running. This work proposes a multi-agent system which allows to learn and to anticipate users' behavior and to adapt at the change into a dynamic mode, and where storing information from the previous cases during successive execution is no more compulsory.

Keywords: classifiers, multi-agent systems, ambient intelligence

1. Introduction

Introduced by Weiser ambient computing consists rather in integrating a computer system directly into the real world, than limiting it to a single computer. Such a computer system is then distributed into the environment in the form of physical devices with which the users can interact, depending on their perceptions and location. These systems are subject to a strong dynamic, with the appearance or the disappearance of many heterogeneous devices (such as measuring the users' displacement) at run-time. However, the user may be faced with situations that the developer cannot foresee. Thus, making an exhaustive list of all the situations that the system may face is not possible during the design phase.

The use of classifiers is widespread for this type of study. However, it is not so easy to adapt to users' behavior changes. Among the traditional classifiers, there are classifiers based on decision tree [*6*], probabilistic models [*8*], function-based algorithms [*9*] or fuzzy models [*1*].

Their functioning is efficient enough, while an adjustment is not required by a new user's behavior. Otherwise, it becomes necessary to adapt their learning to the new cases.

This paper focuses on the learning of users' behavior in order to make such ambient systems able to adapt to the user context. To do so, we consider the different suitable classification algorithms so as to associate any situation with the action expected by the user. The algorithms need to remember the previous cases in order to adapt to any change in their environment, such as a change of the users' preferences or the appearance/disappearance of the devices. In this way, they can reboot. In this way, they can reboot the learning from the beginning if the learning seems too much deteriorated. We are looking for a new solution which can perform this dynamic learning and which does not involve the record of any previous cases but a continuous adaptation, depending on its perception. The system is compared with different classifiers in order to evaluate its performance.

To that end, we present the approach of Adaptive Multi-Agent System (AMAS), and the system Amadeus, designed through this approach. We begin to describe its architecture and functioning, and then we will put forward a comparative study between Amadeus and more conventional algorithms.

This article is divided as follows: section two describes the state of art relating to the classifier systems and to the Adaptive Multi-Agent System approach; section three presents the proposed model; section four describes respectively the results obtained and the conclusions.

2. State of the Art

2.1. Classifiers

The classification algorithms include decision trees, decision rules, probabilistic models, fuzzy models, function-based algorithms and ensemble.

These algorithms/this algorithm use different processes to make the classification. The most commons ones are decision rules and trees which make possible the creation of rules that concatenate variables through operators in order to classify a determined case. Among the classical decision rules algorithms, there are RIPPER [*3*], One-R [*4*], M5 [*5*]. Concerning the decision tree algorithm, the most used are C4.5 or J48 [*6*] (those are the same algorithms, but J48 is the java implementation), and CART [*1*] [*7*] (Classification and Regression Trees). The most commons probabilistic models are Bayes [*8*] and the bayesian network [*2*], but this type of models are not very efficient for continuous variables because it is necessary to realize a discretization of the values. The fuzzy models such as K-NN (K-Nearest Neighbors) [*1*] are not always effective because they require the calculation of several measures of distances, so the performance would not be good enough. An alternative algorithm which is actually very used, is the definition of functions as the Support Vector Machine (SVM) [*9*], this process is used to give good results with a good yield because the classification of new instances is low although the construction of the model is time-consuming. Other options are the ensembles such as Bagging [*10*] and Ada-Boosting [*11*].

2.2. Adaptive Multi-Agent System

Adaptive Multi-Agent Systems (AMAS) are based on a local approach to design complex systems for which no solution is *a priori* known. This approach focuses on defining the local behavior of agents to be truly adaptive, while ignoring the purpose of the overall system, but ensuring that the collective behavior is the one expected, ie the system is "functionally adequate". To this end, agents must have a local cooperative behavior. Cooperation is not limited by a simple resource sharing or simply working together, it is grounded on three local meta-rules, applied by every agent that the designer must instantiate depending on the problem to solve: (c_{per}): any signal received by an agent must be unambiguously understood; (c_{dec}): any information from its perceptions should be useful to its reasoning, (c_{act}): its reasoning should make it perform actions which are useful for the others and for the environment.

The AMAS approach can be described as proscriptive because agents must overall anticipate, prevent or repair Non Cooperative Situations (NCS). A NCS appears when at least one of the three previous meta-rules is not locally verified by an agent. Several generic NCS can then be highlighted: *incomprehension* and *ambiguity* if (c_{per}) is not verified, *incompetence* and *unproductivity* if (c_{dec}) is not respected and, finally, *concurrency*, *conflict* and *uselessness* where (c_{act}) is not verified.

This approach has important methodological implications: designing an AMAS is equivalent to defining and assigning rules of cooperation agents. In particular, for a given problem, the designer must 1) define the nominal behavior of an agent, then 2) deduct the NCS which the agent may face with, and finally 3) define the actions that the agent carries out to come back in a cooperative state.

This approach has helped solve several types of problems related to different areas: the real-time profiling, the bioprocesses control, etc. The capacity of the AMAS to resolve complex, dynamic and distributed problems make them ideally suited to resolve the problem of user behavior learning in ambient system.

3. Proposed System

The Based on the approach by AMAS, we designed *Amadeus*, a multi-agent system whose purpose is, for each device of the ambient system, to collect its local context and to adapt its behavior depending of its context. For this, *Amadeus* begins with the observation and the learning of the way the user uses each device and in what context, in order to achieve any recurring action in its place. Any new user action can modify or improve this learning because the latter is continuous during system operation.

An instance of Amadeus is associated with each device (Fig. 1). In each instance, *data* agents represent contextual data which are either collected from local sensors of the device or received from other instances. The *user* agent represents the user satisfaction depending of the user profile the contextual data of the instance. This satisfaction is defined as a value in the range [0, 1]. We present here the operation of *context* and *controller* agents, which ensure the device adaptation in order to maintain the high user satisfaction.

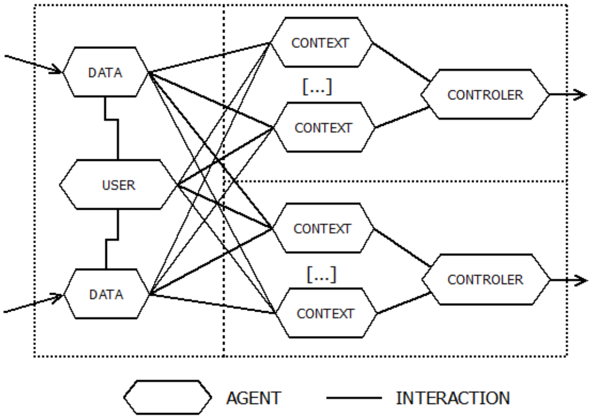

Fig. 1: General structure of the system.

- General Operation

A *controller* agent is associated with each effector of the device. It aims to anticipate the user actions. For this, it has a set of *context* agents, which provides information on the actions it can perform and the consequences of these actions on the user's satisfaction. These *context* agents aim then to determine the effects of a particular action on the user's satisfaction, but also to identify situations where these predictions are correct. In these situations, they view themselves as being valid.

- *Controller* agent

The behavior of *controller* agent is described trough a cycle of three phases. In the perception phase, it collects action proposals from *context* agents. Each proposal contains a description of the proposed action and a forecast of the impact that this action will have on the user's satisfaction, as well as a confidence level for this forecast.

In the decision phase, the *controller* agent evaluates what is the most advantageous action to make among the proposed ones in order to increase the user's satisfaction. To that end, it begins its treatment by managing conflicts or concurrences which oppose the proposals. For example, if two *context* agents propose the same action with different forecasts, the *context* agent will ignore the less confident proposals. Then, once in possession of pertinent proposals, the *controller* agent evaluates what is the best action to do among those proposed by the remaining *context* agents. In other words, it assesses, based on the current situation, which forecast ensures the higher level of user satisfaction. This action may equally be a change in the status of an effector or the maintaining of this effector in its current state, because a *context* agent can propose "preserve the current state" as action.

Finally, in the action phase, it selects the *context* agent associated with the best action, and it makes this action (i.e.: it affects the new state at the effector).

- *Context* agent

A *context* agent has, for each contextual data in the input system, a values' range representing the validity range of the *context* agent. A value range is called *valid* if the current value of this data is included within the bounds of the values range. The *context* agent itself has a validity status, which is *valid* when all its data values' ranges are valid, and *invalid* in the other cases. The *context* agent starts its cycle by validating or invalidating its value ranges, depending on the updated values perceived. Then he does the same with its validity status, if appropriate. The bounds of the values ranges are implemented through an Adaptive Value Tracker (AVT), which is a software component to find the value of a dynamic variable in a given space through successive feedbacks.

A *context* agent owns an action proposal which is sent to the *controller* agent when it becomes *valid*. This proposal includes the description of the action itself, which means the state to allocate at the effector. As well, it includes a forecast about the impact of this action on the user satisfaction, which is implemented as a value between -1 and 1. Finally, it includes a confidence about the forecast, implemented with an AVT limited between 0 and 1, and which means how much the context agent is certain that the proposed action will have the expected impact. When a *context* agent becomes *valid*, it communicates to its associated *controller* agent in order to send it its action proposal. As a matter of fact, a *context* agent considers that the forecast which accompanies the proposed action is true only when the *context* agent is *valid*.

The *context* also has a selection state. It can be *selected* or *unselected*. As I said, a *context* agent is selected if its proposal seems to be the best for the *controller* agent. If another *context* agent is then selected, the previous selected *context* agent becomes automatically *unselected*. If the *context* agent is selected, it records the current level of user satisfaction. Once it is no longer selected, it makes the comparison of the effect produced on the user satisfaction with his prediction possible. Three cases can occur:

1. Forecasts match perfectly to reality: the *context* agent increases his confidence.

2. The forecast value differs from reality, but the forecast meaning is correct: the *context* agent adapts its prediction to rectify it, but nevertheless considered that the action was good enough to increase its confidence.

3. The forecast meaning is incorrect: the *context* agent first decreases confidence. Moreover, it considers that the current environment was not good for the proposed action achieves the expected forecast. Therefore, it changes its input ranges to invalidate the current situation.

The behavior of a *context* agent is to propose an action for a given context with a certain forecast about the consequences of this action on the user satisfaction. Besides, it evaluates its confidence as the reliability of its proposal. In other words, more the confidence is high, more the agent has the certainty that its proposed action will have the expected consequence. This confidence is calculated by a function that evaluates a confidence level T_{t+1} at time t+1 based on its confidence level T_t to the previous time, a feedback F included between 0 and 1, and a parameter λ determined experimentally and which represents the impact of feedback in the calculation of the new confidence level. To increase the confidence of the *context* agent in cases 1 and 2 described above, we use a feedback close to 1, while we use a feedback close to 0 to decrease it in the third case. This function is as following:

$$T_{t+1} = T_t * \lambda + F * (1 - \lambda)$$

A context agent is created each time the user performs an action when no context agents proposed this action for this situation (including the action to "do not change the state of the effector"). This new context has initialized with this action, and its values ranges are initialized around actual values data. The forecast is based on the observed impact of these actions the first time, and the confidence is initialized at 0.5.

Finally, the learning of user behavior is based on the interaction of *context* and *controller* agents. It is produced through the creation of *context* agents, the adaptation of values ranges and the adjusting of *context* agent confidence.

4. Case Study

We made this study in order to compare the performances of *Amadeus* with more conventional learning algorithms. More specifically, we focus on the classifier algorithms Naive Bayes, J48, SVM and LMT, which are well-known techniques for this type of problems. We made this study in order to test the *Amadeus* capacity to determine, for a given situation, what the user action will be. Each situation can be considered as a case, as defined by the Case Base Reasoning approach, or as a contextual situation, as defined in *Amadeus*.

In order to make this evaluation, we designed a simulator of ambient system which makes possible the description of simulated users' simple behaviors in a virtual ambient. We define our ambient system as an apartment where we use a lamp and a shutter, both electric, in the living room. In addition to that, we add on the same room a luminosity and presence sensor.

As for the user, the simulator enables to describe the virtual users' behavior. For now, we set the maximal numbers of users to a single user; the multi-users problems will be dealt with in a future study. We design this virtual user with a simple behavior: he walks randomly in the apartment, making sure that the brightness is suitable when he is in the living room, but he remains energy efficient.

In practice, this means that when he is in the living room, if it is too dark he will first try to illuminate the room by opening the shutter, then light up the lamp if it is not enough light. If the brightness is too high, he will first turn the lamp off if it is on, otherwise he will close the shutter. On the other hand, when he is not in the living room, he does not care about the shutter's state, but he makes sure that the lamp was efficiently turned on. This behavior is much more than maintaining a constant average brightness in the room, because it takes into account the presence of the user in the living room, and the priority to open the shutter rather than to switch the lamp on in order to ensure that the energy is saved if it is possible. As for the user's movements, a random displacement enables to change when and how long the user is or is not present in the living room. To improve the realism of the simulation, the conditions associated to the user's actions are unclear; for example, if the theoretical condition where the user turns on the light is a luminosity above 55, then the real condition will be randomly fixed between 50 and 60. As a matter of fact, a human behavior cannot be modeled with too precise rules of actions.

In order to compare the result produced by *Amadeus* with the result of others classifier algorithms, we generate 13 days of data. The simulator generates a simulation where the time is accelerated, with 1440 simulation cycles by virtual day, one by minute.

The first days (from 1 to 3) are allocated to the learning phase and the next 10 days are allocated to the tests on the effects of the learning. We perform this experiment in two different conditions: in the first one, the learning phase lasts only one day, and over this period we give only the first day data to various algorithms so that they make their learning; in the second condition, 3 days are used for the learning phase. Therefore, we can compare the impact of the learning time on the different systems.

In the Table 1, we can see an example of data perceived by the different learning algorithms. We can see the date from the cycle 480 until the cycle 490 of the first day (i.e. from 8h until 8h10 of the first day). At this moment, the user is in the living room (Presence=1), the shutter is open (Blind=1), the light is turned on (Light=1). The user behavior sets the max threshold of luminosity at 90, and the more the luminosity is beyond the threshold, the more the user's satisfaction decreases. As I previously explained, the threshold, which is set so that the user acts, is randomly generated in order to improve the simulation realism. Here, the generated threshold is at 26%. As a matter of fact, we can see in the cycle 485 that, whereas his satisfaction decreases until this value, the user decides to turn the light off. (User Decision=0).

The objective of our learning is to see, according to these data, what the user's decision is in order to be able to anticipate its decision. Note that the number of the day and the number of the cycle, if they are used to save the previous problem on the conventional algorithm, are not directly used to make the learning of the behavior.

Table 1: Example of data, as perceived by the different learning algorithms.

Day	Cycle	User Satisfaction	Luminosity	Presence	Blind	Light	User Decision
0	480	34%	91,97	1	1	1	1
0	481	32%	92,06	1	1	1	1
0	482	31%	92,16	1	1	1	1
0	483	29%	92,26	1	1	1	1
0	484	27%	92,35	1	1	1	1
0	485	26%	92,45	1	1	1	0
0	486	100%	74,03	1	1	0	0
0	487	100%	74,11	1	1	0	0
0	488	100%	74,18	1	1	0	0
0	489	100%	74,26	1	1	0	0
0	490	100%	74,33	1	1	0	0

5. Results and conclusions

In order to verify Amadeus' adaptability, we test the system evolution through 18 720 cases (one case by minute during 13 days). We capture the data which refer to these cases and we test the success rate when new case arrives in the system. In order to verify the real adaptability from the initial step on, a validation is performed after the capture of information from the first day, in which there were 1440 pieces of data. A learning is performed, using the information of the first day, then as new case are coming, the system foresees the associated user’s action.

We perform a new training of the system only when the classification of a new element is wrong in order to integrate the new case at the used models in the classifiers.

In order to ensure that the system has adaptation and evolution capacities, we use two other variables as the user preferences change, they represent the number of the day and the case number (which is daily reset to zero). If the user preferences change, these variables refer to the case information and the system would be able to adapt itself.

In order to conduct this analysis, we study the system evolution by comparing the multi-agent system Amadeus with 4 different classification systems: the J48, the Naive Bayes, SVM and LMT. In the Fig. 1, we can see the system evolution for the estimation of the light state depending on variables defined in the case study. The axis x represents the case number, and the axis y is the number of accumulated errors. We can see that most of the algorithms have a similar behavior until the moment where the multi-agent system becomes worst than the others. The method with high performance is LMT but the execution time is too high.

In the second experiment, we repeat the same process with 3 days as learning basis. We use the same classifiers and we obtain the results represented on Fig. 2. The Fig. 2 shows the successful rate of the SMA is better than the other methods until the user adapts a new behavior, then the successful rate of the LMT is better than the SMA but this algorithm is not efficient and the execution time is too high. The execution time to carry out the test was 5177.89s and the execution time of the others methods was lower than 60 ms.

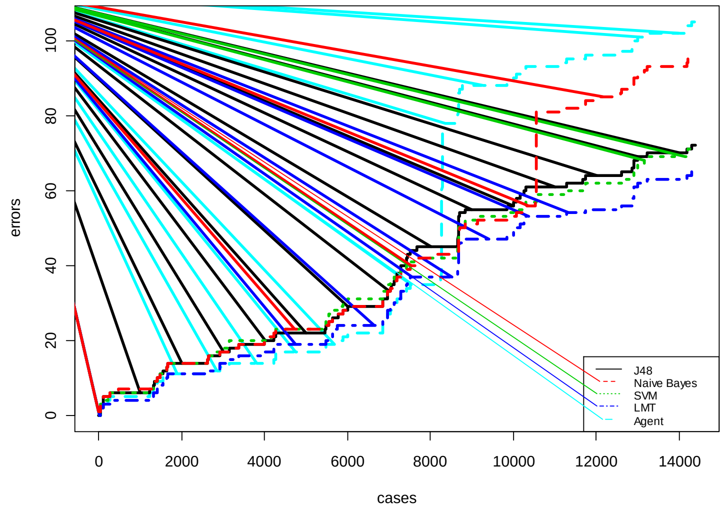

Fig. 2: Evolution of the number of errors made by the CBR with learning based on one day.

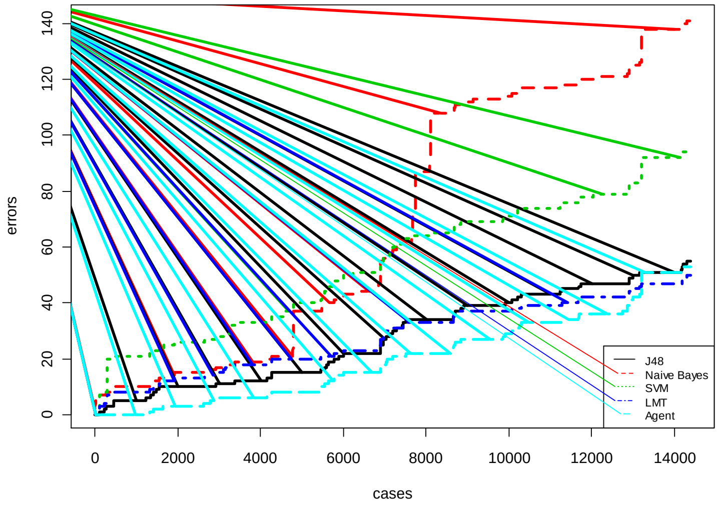

Fig. 3: Evolution of the number of errors made by the CBR with learning based on three days.

The multi-agent system has initially less generalization ability than the others classifiers, but better performances when new cases come. Moreover, Amadeus is able to adapt itself at new situations without it is necessary to store these new cases, facilitating the management of the necessary data for the correct functioning of the system.

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Advantages of using RTLS and WSN to enable efficient power consumption

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Abstract

The use of Real Time Locating Systems is gradually spreading in different areas of society. Multiple sectors, such as industry, security or healthcare are already taking advantage of the benefits of knowing the exact position of people, animals or objects. Energy consumption can also be improved by the use of RTLS and thanks to these systems we can model the habits of users both at home and in public buildings. This information will create consumption maps based on the use of different electronic devices or the use of different spaces. Thus, the election of the best energy tariff or when the best moment is to use appliances will be an easier process.

Keywords: Real Time Location Systems, Wireless communication, Energy Consumption, Energy Tariff, Energy Savings

1. Introduction

Wireless Sensor Networks (WSN) are used for gathering the information needed by intelligent environments, whether in urban construction and Smart Cities, home and building automation, industrial applications or smart hospitals [*1*, *2*]. Wireless Sensor Networks support current requirements related to the deployment of networks that cover communication needs, and flexibly in time, space and autonomy, without requiring a fixed structure [*3*, *4*].

One of the most interesting applications for Wireless Sensor Networks is Real-Time Locating Systems (RTLS) [*5*]. Although outdoor locating is well covered by systems such as the current GPS or the future Galileo, indoor locating needs still further development, especially with respect to accuracy and the use of low-cost and efficient infrastructures.

On the other hand, energy consumption is one of the problems in which more efforts are being carried out. The efficient use of energy helps the sustainability of the planet and allows saving natural resources and reducing pollution.

Monitoring energy consumption is considered as a fundamental tool in optimizing the use of energy resources. In this sense, technology becomes a key tool to collect real-time information and present statistics from the energy consumed by any device.

Buildings and houses are places where the application of technologies for monitoring energy consumption will be more efficient due to the high energy costs associated with. The consumption of the appliances, points of light, air conditioning and heating boilers are critical points where energy leaks appear and their optimization reduces significantly the global energy consumption. Moreover, choosing the most favorable electricity tariff permits increase savings in energy consumption and reduce the cost for the users.

This paper presents the implementation how WSN and RTLS can help to optimize the energy consumption in houses and buildings by knowing the location of users and their behaviors while using energy.

The rest of the paper is structure as follows: Section 2 presents the background of the problem. After that, Section 3 presents how electrical energy consumption is in the residential Spanish market. Section 4 gives a brief description of how can energy consumption can be optimized by the use of RTLS and WSN. Finally, Section 5 presents conclusions and future work.

2. Background and Problem Description

T The optimization of energy consumption is one of the problems that most affect society and more efforts are being used to try to improve it. To this end, research and work make use of all kinds of techniques and technological advances. There are several key aspects to determine how and when energy is consumed in homes. On the one hand, it is necessary to know which devices are consuming energy. On the other hand, it is important to know the users' behavior in order to determine if they are making an effective use of the energy or if they are choosing the best moment to do it. WSN and RTLS have a great potential when used to get all the data to analyze consumptions, determine behavior patterns of the users or optimize the use of the energy in an automatic way.

There are several wireless technologies such as ZigBee, Wi-Fi or Bluetooth that enable easier deployments than wired ones, avoiding the need to wire buildings and decreasing the costs and drawbacks of the setup phase. WSNs make it possible to build a wide range of applications, such as control of energy costs, monitoring of environmental data, security and access control in buildings, as well as industrial and home automation, among many others. In this regard, telemonitoring (or sensing) allows to obtain information about users and their environment, which is taken into account when offering them customized services in line with their environment status. The building automation and control systems market has reached in the world of standards, protocols and data distribution systems, which allows building automation systems, such as security systems, lighting systems and others, to interact and integrate with each other [*6*]. The building automation and control systems which started with wired technology have now entered the era of wireless technology with the advent of technologies such as ZigBee, Z-Wave, EnOcean, and others. Not only building automation and control products have increased living standards and allowed for more convenient lifestyles, they have also saved power through devices such as dimming systems and sensors. Among all the available products, security control has dominated the building automation and control market as a result of increasing concerns to enhance security. Furthermore, building automation & control systems can save up to 80% of power.

Furthermore, for the first time in human history, more people now live in cities than in rural areas, and in the next 20 years the urban population is expected to grow from 3.5 billion to 5.0 billion people [7]. The social, economic, environmental, and engineering challenges of this transformation will shape the 21st century. The lives of the people living in those cities can be improved – and the impact of this growth on the environment reduced – by the use of "smart" technologies that can improve the efficiency and effectiveness of urban systems. The smart city can be defined as the integration of technology into a strategic approach to sustainability, citizen well-being, and economic development.

Some of the applications of Real-Time Locating Systems include tracking people, assets and animals, access control, wander prevention, warning and alert systems, controlling security perimeters, or resources optimization. Companies need to use some sort of monitoring system to track their human and technical resources, and especially, to improve their security, efficiency and safety, and reduce occupational hazards. User identification is a key aspect for adequate services customization and environment interaction. This way, the system can identify each user, know where they are, and automatically provide them with services, without actually requiring the user to initiate the interaction. Knowing the exact geographic location of people and objects can be very useful in a wide range of application areas, such as industry or services. The advantage of knowing and visualizing the location of all the resources in a company and how they interact and collaborate in the different productive processes is a clear example of the demand for a platform that integrates location and automation features in a unique infrastructure. Another good example of this demand includes emergency situations where it is necessary to locate people, such as the case of forest fires or nuclear disasters. The development of a platform for remote location and automation that integrates different subsystems demands the creation of complex and flexible applications [8].

The scope of this work includes the use of RTLS and WSN that allow us to monitor the movements of users in their homes, in order to determine their behavioral patterns in relation to the use of appliances. With this data, we will be able to know when they are using a concrete appliance (e.g. the washing machine) and determine if it is the best moment according to the tariff rate.

Next Section presents how energy consumption is in the Spanish market. This information allows identifying the most susceptible consumptions to be optimized by the use of RTLS and WSN.

3. Energy consumption in the residential sector in Spain

The average consumption of a Spanish household is 10,521 kWh per year (0,038 TJ), being predominant in terms of final energy, fuel consumption, 1.8 times the electricity consumption. 62% of electricity consumption due to the electrical equipment, and to a lesser extent lighting, cooking and heating services and hot water. Table 1 shows in detail how this consumption is.

Table 1: Average energy consumption in a typical household in Spain.

	FINAL CONSUMPTION					
	Electrical	**Fuels**	**TOTAL**	**Electrical**	**Fuels**	**TOTAL**
Final use	TJ	TJ	TJ			
Heating	15.907	272.667	288.574	2,59%	44,38%	46,96%
Hot water	16.129	100.114	116.243	2,62%	16,29%	18,92%
Cooking	20.063	25.588	45.651	3,27%	4,16%	7,43%
Refrigeration	5.042	107	5.149	0,82%	0,02%	0,84%
Lighting	25.366		25.366	4,13%		4,13%
Appliances	133.468		133.468	21,72%		21,72%
Fridge	40.834		40.834	30,59%		30,59%
Freezer	8.083		8.083	6,06%		6,06%
Washing machine	15.812		15.812	11,85%		11,85%
Dishwasher	8.080		8.080	6,05%		6,05%
Dryer	4.469		4.469	3,35%		3,35%
Oven	11.022		11.022	8,26%		8,26%
TV	16.263		16.263	12,18%		12,18%
PC	9.906		9.906	7,42%		7,42%
Stand-by	14.292		14.292	10,71%		10,71%
Other equipment	4.707		4.707	3,53%		3,53%
TOTAL CONSUMPTION	**215.975**	**398.476**	**614.451**	**35,15%**	**64,85%**	**100,00%**

As can be seen in the following graphs (Fig. 1 and 2), there are some consumption that would be easily optimized through the use of WSN and RTLS. Among them, heating can be optimized by using a correct schedule depending on the hours when users are at home or even regulate its operation by areas depending on the occupation of spaces.

Other optimizable consumptions are the use of some appliances, by taking into account the day and the hour they are used, lighting by WSN and presence or location and the stand-by consumptions by the hours of charging of the devices.

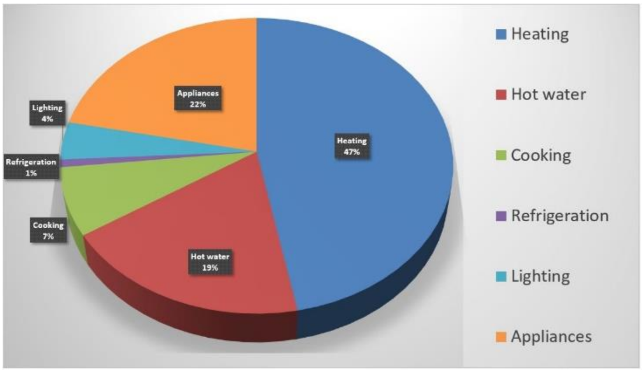

Fig. 1: Consumption by utilities in a typical household in Spain.

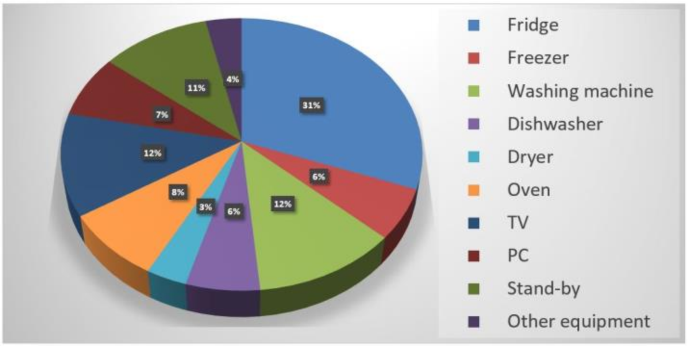

Fig. 2: Consumption by appliances in a typical household in Spain.

4. How do RTLS help?

RTLS are used for determining the position of a mobile element throughout the environment. This includes to locate people around their homes as we can see in Fig. 3. With this information we are able to know:

- When consumers are at home.
- Where consumers are into the household.
- What consumers are doing.

Moreover, the use of WSN permits to collect different information and to act over several elements, such as:

- Real-time meter monitoring implies knowing consumption in real-time.
- Light sensors to identify the level of natural lighting.
- Presence sensor, to turn off automatically lights or heating if there is no presence.

With this information, different patterns of users' behaviors inside their homes can be identifies. These patterns allow us to define schedules of staying at home, when cooking or laundry is done, what are the hours of rest or which rooms are not in use.

On the other hand, the electricity tariff rate in Spain changes every day and the energy has different cost depending on the day or hour it is demanded, as Fig. 4 shows.

Combining the information collected by the RTLS and WSN and the tariff rate, it is possible to improve the use of energy at homes by recommending users alternative hours and days to carry out some task scrollable in time (such as laundry or drying clothes) or avoid unnecessary consumptions by using automated switches.

All these things seem obvious, such as, control the stand-by at night. For example, if stand-by are reduced 100W, the savings are 100 W x 8 hours x 365 days = 292 kWh / year. According to the CNMC, the average domestic consumption in Spain is 2,630 kWh / year, so turning off the devices when sleeping implies savings of at least 10% of the annual consumption.

Fig. 3: Example of use of RTLS at home to determine positions and behaviors of users.

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
00:00	0,1193	0,1215	0,1198	0,1211	0,1216	0,1188	0,1149
01:00	0,1144	0,1170	0,1158	0,1183	0,1167	0,1146	0,1096
02:00	0,1139	0,1140	0,1135	0,1155	0,1148	0,1117	0,1076
03:00	0,1134	0,1133	0,1129	0,1155	0,1150	0,1115	0,1064
04:00	0,1125	0,1137	0,1126	0,1148	0,1144	0,1114	0,1065
05:00	0,1137	0,1151	0,1137	0,1144	0,1154	0,1120	0,1062
06:00	0,1204	0,1200	0,1195	0,1199	0,1211	0,1128	0,1075
07:00	0,1243	0,1252	0,1251	0,1225	0,1264	0,1126	0,1052
08:00	0,1275	0,1281	0,1285	0,1265	0,1285	0,1197	0,1089
09:00	0,1308	0,1305	0,1308	0,1291	0,1306	0,1231	0,1107
10:00	0,1304	0,1302	0,1303	0,1287	0,1300	0,1247	0,1116
11:00	0,1311	0,1303	0,1303	0,1287	0,1300	0,1262	0,1134
12:00	0,1300	0,1286	0,1283	0,1271	0,1285	0,1240	0,1118
13:00	0,1289	0,1286	0,1274	0,1261	0,1274	0,1245	0,1133
14:00	0,1269	0,1256	0,1245	0,1239	0,1255	0,1217	0,1125
15:00	0,1233	0,1229	0,1217	0,1210	0,1222	0,1146	0,1053
16:00	0,1230	0,1227	0,1215	0,1215	0,1220	0,1116	**0,1036**
17:00	0,1238	0,1239	0,1229	0,1228	0,1231	0,1115	0,1042
18:00	0,1259	0,1252	0,1248	0,1255	0,1245	0,1158	0,1113
19:00	0,1296	0,1280	0,1271	0,1280	0,1262	0,1196	0,1173
20:00	0,1322	0,1311	0,1300	0,1307	0,1290	0,1239	0,1234
21:00	**0,1356**	0,1347	0,1337	0,1340	0,1329	0,1292	0,1325
22:00	0,1311	0,1303	0,1296	0,1297	0,1295	0,1261	0,1304
23:00	0,1238	0,1230	0,1232	0,1238	0,1233	0,1183	0,1221

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Fig. 4: Electricity price in Spain depending on the hour and day of consumption.

Table 2 shows how much money can be saved at each home by optimizing the parameters outlined before. Although the savings may not seem relevant, if it is when you consider the volume of homes and the amount of energy wasted by misuse.

Table 2: Cost of use and savings of appliances energy consumption according to the Spanish electricity market tariffs..

	Consume (W/h)	Mx. Price	Av Price	Min. Price	Difference	Yearly
Price		0,1356 €	0,1196 €	0,1036 €		
Cooking	2.200	0,2983 €	0,2631 €	0,2279 €	0,0704 €	25,6960 €
Fridge	110	0,0149 €	0,0132 €	0,0114 €	0,0035 €	0,0000 €
Freezer	842	0,1142 €	0,1007 €	0,0872 €	0,0269 €	0,0000 €
Washing machine	1.050	0,1424 €	0,1256 €	0,1088 €	0,0336 €	6,9888 €
Dishwasher	1.148	0,1557 €	0,1373 €	0,1189 €	0,0367 €	5,7308 €
Dryer	270	0,0366 €	0,0323 €	0,0280 €	0,0086 €	1,7971 €
Oven	1.200	0,1627 €	0,1435 €	0,1243 €	0,0384 €	9,9840 €
TV	156	0,0212 €	0,0187 €	0,0162 €	0,0050 €	3,6442 €
PC	64	0,0087 €	0,0077 €	0,0066 €	0,0020 €	2,9901 €
Iron	1.200	0,1627 €	0,1435 €	0,1243 €	0,0384 €	3,9936 €
Hair dryer	1.875	0,2543 €	0,2243 €	0,1943 €	0,0600 €	6,2400 €
						67,0646 €

5. Conclusions and Future Work

The present text explains how RTLS and WSN can help to monitor consumptions and to identify users' habits and behaviors. With that data and information, new models of analysis can be design and developed. This models allow to improve the use of energy and avoid unnecessary consumptions.

However, the most important point of all the issues discussed above is aware users of the efficient use of energy at optimal times and promote environmentally friendly habits.

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Simulation of consumers and markets towards real time demand response
First DREAM-GO Workshop

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Embedded agents to monitor sounds

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Abstract

Ambient intelligent has advanced in the last years. The inclusion of Artificial Intelligent techniques, as pattern recognition, has allowed these systems to have a better adaptation to the environments. In this work, a multiagent system based on PANGEA and embedded agents to manage and monitor alarms is shown. The system incorporates embedded agents in Arduino hardware devices with modules to detect sounds and luminosity bands.

Keywords: virtual organizations, ambient intelligent, sensors.

1. Introduction

During the last years, ambient intelligent has evolved [*2*] [*3*], and it is becoming more relevant in the daily life [*6*] - [*8*]. The ambient intelligent techniques adapt the technology to the needs based on three concepts: ubiquitous computing, ubiquitous communication, and intelligent user interface. To reach these objectives it is necessary to develop new frameworks and models that allow to access to the information regardless of the location. Wireless sensor networks (WSN) [*4*] [*5*] [*18*] provide an infrastructure that allows to distribute the communication in dynamic environments. Multiagent systems are a good alternative to manage the information of sensors. There are proposals that combine the multiagent systems and WSN to build intelligent environments [*11*] - [*16*] nevertheless, it is important to develop a multiagent system to work with virtual organizations and embedded agents.

In this paper, a model of agent that can be executed as embedded hardware in an Arduino is shown. The agent is developed inside PANGEA [*22*], which is a multiagent architecture based on virtual organizations, oriented to create intelligent environments. The system incorporates a module for Arduino in order to detect sounds and control luminosity bands. PANGEA incorporates the Sensor agent that can be incorporated in lightweight devices. This agent has been incorporated in the Arduino [*10*] helping to manage the information obtained from different devices. The paper is structured in these sections: section 2 is a brief overview about the PANGEA platform is shown with the information about the sensor agent, section 3 includes information about the case study, results and conclusions.

2. Platform PANGEA

With the evolution of the ubiquitous and distributed systems, it is necessary to develop new platforms of agents that facilitate the development of open multiagent systems with the ability to be deployed in several kind of devices. PANGEA [*22*] is a multiagent platform with organizational aspects which allows to model and develop open systems, enhancing the distribution of resources and management of the nodes in which the agents are deployed. PANGEA has several virtual organizations that are deployed automatically within the initiation of the platform. The organizations are the following:

- Translator Organization: The agents deployed in this organization are in charge of the translation and communication with agents which do not share the same Agent Communication Language (ACL) used by the PANGEA agents. PANGEA agents are implemented in Java or C++ and use the standard Internet Relay Chat (IRC) as communication language.
- Central Control Organization: this organization includes the agents that manage and control the entire platform.
- Organization for External Monitoring: This organization includes those agents deployed in external monitoring devices such as cameras, sirens, etc.

2.1. Sensor Agent

Embedded systems are designed to carry out specific or simple functions. The main characteristics that represents the use of embedded system with regard to other computational systems is their low fabrication cost, and its low capacity. There are many micro-controllers available in the market, the best known are Arduino[*19*], Propeller[*20*], Beagle Board [*21*] and Raspberry Pi [*1*]. The Arduino board uses in the development is the model Arduino Duemilanove [*24*], that contains the components shown in the Fig. 1.

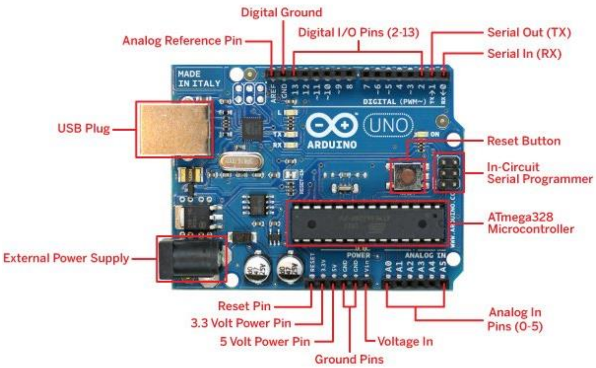


Fig. 1: Components in the Arduino board.

The Duemilanove model contains an ATmega168 or ATmega328 microcontroller [*25*]. It has 14 pins, where 6 can be used as PWM (*Pulse Width Modulation*) [*27*] and 6 for analogic signals. Besides, it has a reset button, a USB connection to communicate with a computer, and 2 pines to communicate through ISC protocols [*26*].

2.1.1. Module Sound Recognition

Both the acoustic treatment and analysis are carried out by means of EasyVR [*28*] board. It provides a good connectivity with any controller through an UART communication [*29*]. The sounds to be recognized are stored in an internal memory with a capacity of 32 sounds. EasyVR has a microphone that allows capturing and detection in real time the sound in the environment.

The minimum input voltage of this shield is 3.3V, so it is a good candidate to work with the Arduino Duemilanove board. A scheme of this module is shown in Fig. 2.

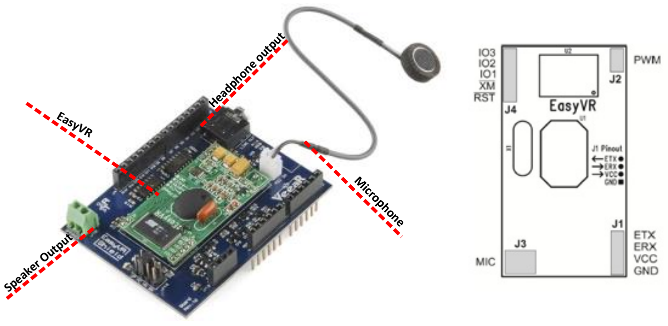


Fig. 2: Sound recognition module for Arduino.

2.1.2. Scheme Solution

The sensor agent has the hardware components shown in the Fig. 3:

- Arduino Duemilanove board.
- Sound recognition module EASYVR.
- Luminosity band.

The microphone is continuously monitoring the sound; when the system detects a pattern similar to any of the ones stored in the memory, the system reproduces a luminosity pattern to send a warning to the users. This is useful for deaf people, who are hindered to hear an acoustic alarm from a conventional device.

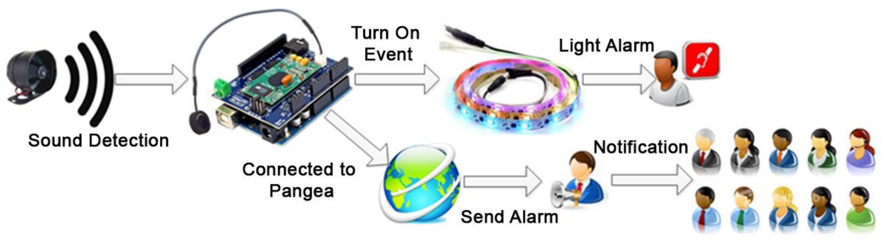


Fig. 3: Integration of Arduino and EASYVR in the architecture PANGEA.

The microcontroller is connected to the PANGEA architecture. This sensor uses the connectivity and the services provided by the system to send the alerts and notifications to the users.

2.1.3. Algorithms

The following figures show the algorithms responsible to manage the luminosity alerts in order to turn on and turn off the luminosity bands.

```
void TurnOnLED(){
        while (1){
          // Update the colors.
          byte time = millis() >> 2;
          for(byte i = 0; i < LED_COUNT; i++)
          {
            byte x = time - 8*i;
            colors[i] = (rgb_color){ x, 255 - x, x };
            //colors[i] = (rgb_color){ 0, 0 , 0 };
          }
          // Write the colors to the LED strip.
          ledStrip.write(colors, LED_COUNT);
          delay(10);
        }
}
```

```
void TurnOffLED(){
        // Update the colors.
        byte time = millis() >> 2;
        for(byte i = 0; i < LED_COUNT; i++)
        {
          byte x = time - 8*i;
          //colors[i] = (rgb_color){ x, 255 - x, x };
          colors[i] = (rgb_color){ 0, 0 , 0 };
        }
        // Write the colors to the LED strip.
        ledStrip.write(colors, LED_COUNT);
        delay(50);
}
```

The algorithm "read_from_server" is responsible to check if there are requests from the PANGEA server to our agents, in this case, the response is calculated depending on the request.

```
void procesarSonido(){
 easyvr.setPinOutput(EasyVR::IO1, HIGH); // LED on (listening)
  read_from_server();
  easyvr.recognizeCommand(group);
  do
  {
    //WAIT
  }
  while (!easyvr.hasFinished());
  easyvr.setPinOutput(EasyVR::IO1, LOW); // LED off
  idx = easyvr.getWord();
  if (idx >= 0)
  {
    // built-in trigger (ROBOT)
    // group = GROUP_X; <-- jump to another group X
    return;
  }
  idx = easyvr.getCommand();
  if (idx >= 0)
  {
    // print debug message
    uint8_t train = 0;
    char name[32];
    Serial.print("Command: ");
    Serial.print(idx);
    if (easyvr.dumpCommand(group, idx, name, train))
    {
      Serial.print(" = ");
      Serial.println(name);
    }
    else
      Serial.println();
    easyvr.playSound(0, EasyVR::VOL_FULL);
    action();
  }
  else // errors or timeout
  {
    if (easyvr.isTimeout()){
      //read_from_server();
      Serial.println("Timed out, try again...");
    }
    int16_t err = easyvr.getError();
    if (err >= 0)
    {
      //Serial.print("Error ");
      //Serial.println(err, HEX);
    }
  }
}
```

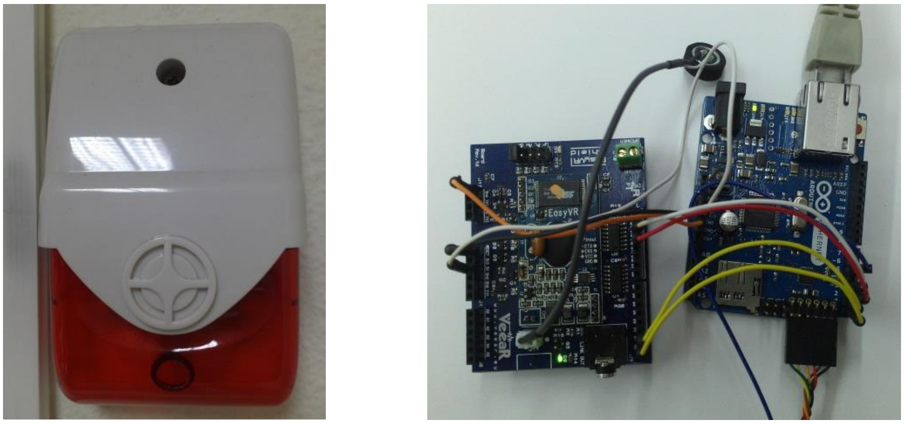
```
void read_from_server(){
  String a_sentence;
  String response;
  String after_space;

  while (client.available()){
    c = client.read();
    a_sentence = "";
    //pull out characters from the client serial and assemble a string
    while (client.available() && c != '\n'){
      a_sentence = a_sentence + c;
      c = client.read();
    }
    response = command_response(a_sentence);
    //todo, stuff to detect if the message was sent from/to a pm or a channel
    //  and direct the response back to that channel
    Serial.println(a_sentence);
    if (response != ""){
      printlnBoth(response);
    }
  }
}
```

The algorithm "procesarSonido" initializes the module EASUVR and it remains listening in order to detect patterns. When the module detects a sound, it executes the function action() that will manage each sound.

3. Case study: intelligent environment to detect alarms

The system has been developed in the laboratory of the research group. The laboratory contains different kind of sensors such as: luminosity, temperature, presence, alarms, locations and other sensors connected with ZigBee. The objective of the work is to detect the alarms through the sound without connecting them to the system, so that the system can be used with any hardware, for example gas, smoke detector, rings etc. This is an important issue in order to reduce cost.

The Fig. 4a) shows the image of an alarm in the laboratory, the Fig. 4b) shows the EASYVR connected to the Arduino.



(a) (b)

Fig. 4: a) Alarm b) EasyVR.

During the test, we have used these alarms: smoke, gas, stole, ring that reproduces different pattern in the luminosity band shown in the Fig. 5.

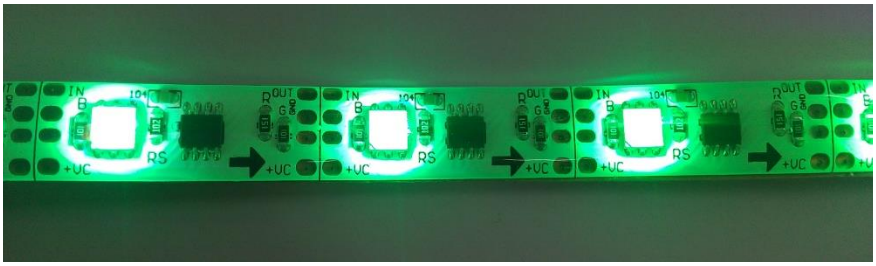


Fig. 5: Luminosity band.

Finally, to analyse the performance of EASYVR, the sounds were modified with a filter. Fig. 6a) shows the spectrum of the original sound, and Fig. 6b) shows the spectrum after applying a tremolo filter. The system was able to detect the sounds with this filter and White noise.

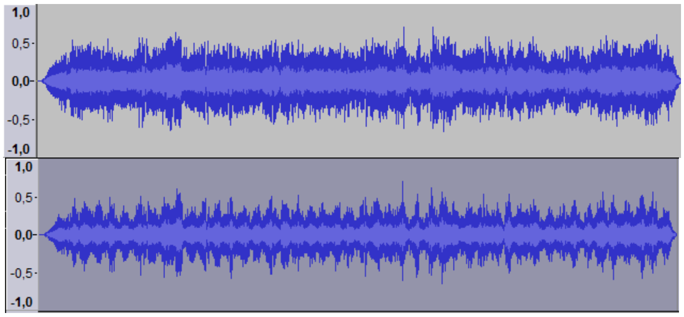


Fig. 6: a) Original sound; b) sound after tremolo filter.

The PANGEA architecture allows to interconnect devices facilitating the integration of information and the decision making from the information provided by the sensors. This interconnection allows to communicate the devices and process the information in lightweight devices.

The proposal incorporates agents in Arduino devices, this is important because it facilitates the integration of sensors and actuators in the PANGEA platform.

Arduino in combination with the module EASYVR allow us to recognize different sounds and register behaviour according to these patterns. The sound recognition is important since it reduces the costs, as it facilitates the incorporation of devices without using a WSN.

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Simulation of consumers and markets towards real time demand response
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Evaluation of Smart Grid Implementations in the Consumer's Energy Bill

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Abstract

The need to increase the share of renewable energy resources in several countries around the world led to the development of new strategies, in order to implement more effective energy policies. These resources have a distributed nature and are one of the main paths to incentive the reduction of CO2 emissions, and their impact on the environment. Many countries are making efforts to advance in the implementation of their own strategies to achieve the fossil fuels independency. Therefore, the intent is to stipulate energy policies that increase renewable energy share in the energy mix. These policies depend on regulations, taxation, incentives and promotional schemes. In this paper, it is presented a brief introduction to the energy policies in two countries, Denmark and Finland. Demand Response (DR) aspects and its impact in the energy market are also discussed.

Keywords: demand response, distributed generation, energy markets, energy policies, smart grid

1. Introduction

The smart grid (SG) is a study field of growing importance and interest. It is associated to the development of the electrical grid, in terms of network trustworthiness and in energy quality, which significantly improves its efficiency. SG is expected to improve grid reliability since it provides the means to controlling and managing the power generation and consumption. As it is described in [*1*], a SG intends to introduce Distributed Generation (DG) in the electrical grid by maximizing the penetration of renewable energy sources, and to foster Demand Response (DR) programs through active consumers participation in network operation.

Several countries around the world are planning strategies to reduce their dependency on fossil fuels, aiming to reduce CO_2 emissions. Therefore, the implementation and high penetration of DG can bring several benefits regarding this issue. This type of generation, many times referred as decentralized generation, is considered a good solution, also reducing the need of improving the high voltage transmission system. It's implementation represents a measure of small investment, once it is located near the consumer, avoiding long distance transmission lines [*2*]–[*4*].

Demand Side Management (DSM) consists on means developed in order to improve the energy system management, operating in the consumption-side [*5*], [*6*]. DR is often defined as changes in electricity usage by end-use customers from their normal consumption patterns in response to changes in the electricity price (price responsive DR), or to incentive payments designed to induce lower electricity use at moments of high wholesale market prices or when system reliability is jeopardized [*7*]. Demand response options are divided into Price-Based and Incentive-Based Programs [*8*]. According to the literature, many research focus the demand response price-based strategies, highlighting the following programs: Real-Time Pricing (RTP) [*9*], Time-of-Use Tariffs (ToU) [*10*] and Critical Peak Pricing (CPP) [*11*].

Nowadays, one of the world top priorities is the implementation of sustainable energy policies, allowing the restructuring of the National Renewable Energy Action Plan (NREAP). Therefore, it is essential to shift from non-renewable to renewable energy sources (RES), in order to move towards a sustainable energy system. According to present literature, several barriers need to be addressed in order to increase the penetration of RES. These barriers include cost-effectiveness, technical, market (such as inconsistent pricing models), institutional, political and regulatory, and social and environmental barriers. These challenges differ between countries or regions [*12*].

One of the main barriers is the fact that distributed generation resources are small-sized, dispersed in the distribution level with no direct access to the wholesale market. Nevertheless, a measure was necessary to be considered to solve this problem, therefore the renewable energy resources aggregation was deliberated. This procedure aims to aggregate several generation units, in order to achieve the minimum power required for participation in wholesale market [*13*]–[*15*].

In this paper, two countries are presented in which is intended to perform a comparison between them in terms of energy policies promoted to increase renewable energy penetration and, also, the DR programs implementation. The countries to be studied are Denmark (DK) and Finland (FI). The main purpose of this paper is to give a perspective on how the implementation of DG and DR are being currently developed, including the main difficulties and challenges in its employment.

This paper is organized as follows: section I refers the introduction, section II and III presents a portrayal of Denmark and Finland, in terms of DG, DR and energy policies promoted, respectively, and in section V presents the concluding remarks.

2. Denmark

Since 2012, Denmark has been continuously updating its energy infrastructure in order to adapt it for smart grid integration. Taking into consideration Denmark's 2050 path strategy

[*16*], the share increase of renewable sources into the energy mix will most likely cause difficulties to the balancing and regulation markets. In this way, smart grids are implemented to integrate several types of DER, improving overall efficiency.

2.1. Distributed Generation

Currently, Denmark is a successful case of DG integration with special focus on wind energy resources. The investment is concentrated in sustainable energy (thus reducing energy dependency and costs) and district heating (being a cold region, the needs for heating are significant) [*17*]. Regarding the first issue, it covers the implementation of large wind farms and gradually replacing fossil fuels by biofuels. The potential of biofuels, biomass and biogas, is well recognized by Denmark integrating their strategy for a 100% renewable sources share for 2050.

For the second issue, district heating is accomplished by the installation of small and distributed Combined Heat and Power (CHP) plants [*18*]. These, according with the Danish Energy Agency (DEA), will be a key factor for the large integration of renewable sources, since any excess power produced can be used by CHP plants to produce heat for the community. Having the possibility of enabling heat storage, this strategy can be very useful for the Danish energy infrastructure and their plan for 2050. Considering the Energy Policy Agreement of 2012 [*19*], Denmark defined the path to reach 100% renewables share [*16*]. Also, the support for solar and other small-size installations, has been taken into consideration by the Danish government, publishing an official document named the Agreement of November 2002. Regarding the promotion schemes, Denmark makes use of fixed feed-in tariffs, feed-in premium tariffs, tenders, and tax benefits [*17*]. Tenders are used together with feed-in premium for wind farms, mostly offshore, while fixed feed-in tariffs are applied to other renewables. Tax benefits are also for wind farms installation, normally allowing an initial period of tax-free operation. The duration of these schemes depends upon the technology considered, time of installation, and owner. In this way, the DEA presents promotion strategies for wind (onshore and offshore), biogas plants, solar, wave power, biomass, CHP, and several others. The most relevant and recent subsidiaries schemes for DG in Denmark are [*20*], [*21*] (all prices are in the Danish monetary unit, DKK/kWh):

- **Wind Onshore –** the owner deals with all the activities related with the sale of energy in the energy markets. An allowance of 0.023 is given for balancing costs. The installation receives 0.25, during 6 600 full load hours. The price is reduced in 0.01 each point that the market price exceeds 0.33;
- **Wind Offshore –** the owner deals with all the activities related with the sale of energy in the energy markets. The supplement is divided by energy perimeters, namely, 0.518 (Horns Rev 2), 0.629 (Rødsand 2), and 1.051 (Anholt). This scheme has limits by energy supplied and duration, 10 (Horns Rev 2 and Rødsand 2) or 20 TWh (Anholt) and 20 years;
- **Wind Households –** turbines with less than 25 kW, receive 2.50 during 10 years. If capacity is less than 6 kW, the installation receives 1.30 that is reduced yearly during 4 years in 0.14, in a total of 10 years also;
- **Biogas Plants –** receives a normal tariff of 0.793, however, if capacity is less than 6 kW, then the same conditions of wind households for this situation, are applied in these plants.

These features are only valid for plants using biomass as fuel for production of biogas. Other plants receive 0.431;

- **Solar –** if capacity is less than or equal to 400 kW, the conditions of wind households are applied. If capacity is greater than 400 kW, then for the first 10 years it's applied 0.6, while for the next 10 years it's applied 0.4, in a total of 20 years of promotion. For collective installations, a 1.45 tariff is used and reduced annually by 0.17 for 4 years, in a total duration of 10 years;

- **CHP –** the owner deals with all the activities related with the sale of energy in the energy markets. If biomass is used as fuel, a supplement of 0.15 is given.

It is importance to notice that the promotion of these energy sources are costly, and therefore, the financial reliability has to be assured by the country, taking into consideration the impacts that it causes on the involved parties.

2.2. Demand Response

Demand response in Denmark is still under development, has it can be seen in *[22*]. Although flexibility is possible to be obtained from several resources, the integration of consumers into energy systems presents a sustainable solution. Consumer's flexibility is a fundamental part of smart grids integration, allowing a wide variety of solutions to them [*23*]. Denmark has a few issues on the demand response path, namely, the participation conditions that have not yet been adequate to DR consumers. Independent aggregators are in a disadvantageous position towards internal entities (such as, Balance Responsible Parties – BRPs) and payments are not as attractive as they should be. Considering all of these issues, one can say that Denmark has a long way to go in order to reach smart grids full potential.

According to [*24*], Denmark can have the following advantageous in the implementation of flexibility resources: easily handle seasonal demand variations, and management of fluctuations caused by renewables, peak demand, network balancing and reliability. In Denmark DR resources can access ancillary services, wholesale, and strategic reserves market. Denmark is divided into two transmission zones, namely, Western – DK1 and Eastern – DK2, making their management easier to perform. Table 1, presents the DR programs available in Denmark [*25*].

Table 1: Danish demand resource's programs.

Program	**Details**	**Min. size**
Primary Reserve (DK1)	• This program is activated automatically through the TSO • Max. activation duration of 15 minutes • The loads are notified 30 seconds before activation, having 15 seconds to provide half of reserve • It's used for frequency control when the same is in the interval 49.8-50.2 Hz • Auctioned in a daily basis, with a day-ahead planning, divided into 6 time blocks	0.3 MW

Frequency-controlled normal operation reserve (DK2)	• This program is activated automatically through the TSO • In normal operation, the notification time is 150 seconds, while in disturbance, 50% have to be available within 5 seconds, and the remaining in 25 seconds • Need for frequency measurement equipment, with sensitivity better than 10 mHz • Auctioned in a daily basis, where a part is procured two days before (D-2), and the rest one day before de planning day (D-1) • Max. activation duration of 3 hours when D-1, or 6 hours if D-2 • Disturbance reserves are used when frequency is lower than 49.9 Hz	0.3 MW
Frequency-controlled disturbance reserve (DK2)		
Secondary Reserve (DK1)	• Has a notification time of 15 minutes • Symmetrical bids with up/down regulation • Online metering is needed in this program • Auctioned in a monthly basis	1 MW
Tertiary Reserve	• Is a voluntary participation of consumers, with manual activation • Involves a 24/7 control center to manage	5 MW
Manual Reserve	• Notice time of 15 minutes • Daily auctions, a for all hours of the next day • Used for manual up/down regulation service, helping together with other programs, in frequency problems	10 MW

Additionally, to what is presented above, DR resources can participate in Danish energy markets as strategic reserves, with a maximum amount of 20 MW. This capacity is auctioned on a tender linking producers and consumers, with 24/7 availability.

Although load aggregation is possible, the truth is that external market entities are impaired with internal entities, namely, suppliers/BRPs. In this way, independent aggregators have to accomplish agreements with both BRPs and consumers.

In Denmark's energy infrastructure, BRPs play an important role since all production and consumption has to be known by these entities. Therefore, when consumption is reduced by external entities, the BRP needs to know about it, thus the need for the aggregator to have an agreement with the BRP/TSO.

According to [*26*], aggregators have a relevant role in what concerns DR implementation and the introduction of flexibility in the markets, mainly by two reason:

- Manages retail demand resources, supporting their participation;
- Joins several small-size consumers (aggregation), enabling them to participate in the wholesale markets.

2.3. Progress vs Status Quo

In what concerns the development of renewable energy in the Danish energy infrastructure, wind energy raises as the main source. Wind's high energy share of 39% in the total electricity supply, grants the Danish the rank of one of the best countries in producing renewable energy. According to DEA, by July of 2014, Denmark had 5,252 wind turbines obtaining a total of 4,810 MW of installed capacity (1,271 MW on offshore alone).

Although renewable energy share has been raising considerably, also the electricity costs for the consumers have been increasing over the years, namely, almost 25% since 2007 to 2014, as shown in [*27*]. Developing a renewable energy promotion infrastructure, comes with associated costs. For this, Denmark has introduced the Public Service Obligation, which comes in a form of an electricity supply tax for consumers, being this the major reason for energy price raise.

DR implementation is very limited and information about this is not easily found. Denmark's use for demand response in its energy infrastructure is almost inexistence, except for some participations of consumers in pilot projects or occasional tests for the existing DR programs – status quo in DR.

3. Finland

In this section it is presented detailed information about Finland. It is intended to approach the main barriers that this country faces in implementing DG and DR.

3.1. Distributed Generation

The CO_2 emissions in Finland are fairly high when compared with the international standards. This poor performance is explained by the following: northern European climate, sparsely populated (17 inhabitants/km^2), and its industry that is composed by intensive consumers. These factors lead to a considerable energy use in the heating of homes and other buildings, and in travelling long distances [*28*].

As a member of the EU, Finland is involved in negotiations about climate and energy issues. In 2008, a Long-Term Climate and Energy Strategy was approved by the government, with detailed measures for the period of 2020-2050 [*29*]. Finland has a target to increase the share of renewable energy sources to 38% by 2020.

According to government estimations, the share of electricity in final energy consumption will be around 36% in 2050, while the need for fossil energy will fall by 24 TWh over the period 2005–2020, and by 104 TWh over the period 2020–2050. In 2050, the fossil energy need will be just around 88 TWh [*30*]. In terms of the need of fossil energy, the established target consists in a decrease of 11% by 2020 [*30*].

Finland's energy system has traditionally been based on a strong control and regulation state [*31*]. However, since 2000, the ownership arrangements for the different types of companies, and their roles in the energy sector, have changed becoming less distinguished. Also, a number of foreign energy companies have enrolled the Finnish energy market.

Companies in the energy sector have had to face challenges in managing their energy balance, and in satisfying consumer needs comprehensively [32]. Many experience is gained with the voluntary agreements, which energy operators have devoted themselves to develop a sustainable energy sector [33].

Currently, RES has a share of one third of total consumption, in Finland, where the largest share is from nuclear power [34].

The current policy mechanism that supports RES producers, includes investment subsidies in the form of a state grant ("Energy Aid") and a feed-in tariff system [35], [36]. In the feed-in tariff system, the producer is paid a tariff that is equal to the difference between the target price and the spot market price, over a three-month average. To be eligible in this tariff scheme, the minimum capacity of the generators must be at least 500 kVA for wind and 100 kVA for biogas and biomass [35]–[37]. It is important to refer other conditions, such as producing electricity only for commercial and fulfilling specific long-term economic parameters [36]. Table 2 presents the subsidies applied to each source type, in Finland.

Table 2: Finland subsidiaries summary [37].

Source	Size (MVA)	Basic Subside	Alternative subsidy	Subsidy Condition
Wind	0.5	Difference between €83.5/MWh and market price	• Difference between €105.30/MWh and market price instead of basic subsidy	• Paid until 31/12/15, for max. of 3 years
Biogas	0.1		• €50/MWh heat premium on top of basic subsidy	• Efficiency 50% min. or 75% if nominal capacity of generator exceeds 1 MVA
Wood Fuel	0.1 - 8		• €20/MWh heat premium on top of basic subsidy	

In terms of heat production, three different mechanisms are identified in Finland: the same mechanism that is available for electricity producers, a price-based incentive (called "heat bonus") and a special subsidy for farmers who invest in renewable CHP [36], [37]. The heat bonus is applied only in CHP plants using biogas or biomass, with an efficiency of more than 75%, and having a minimum capacity installed of 1000 kVA. The bonus is fixed at 50€/MWh for plants exploiting biogas and 20€/MWh for plants using wood.

3.2. Demand Response

Finland is one of the world's leaders in terms of DR practical implementation from technology and market perspective [38]. Since the beginning of 2014, almost every end-consumer has a smart meter [39]. At the moment is estimated, based on the viewpoints of the DSO staff, a total of 1800 MW of loads ready to be controlled via smart meters in Finland [39]. Finland has a long experience concerning the remote control of customers' loads. They are responsible for controlling the electrical heating loads based on ToU (Time-of-Use) tariffs for over 30 years [38].

In Finland, DR is supported even for small customers, because practically all customers are settled based on their hourly measured consumption. However, it is possible to verify some limitations in terms of aggregation measures.

The aggregators can combine several consumers belonging to a certain area balanced by the same Balance Responsible Party (BRP). This is a major concern, once it reduces the full potential of DR, because the consumers do not have access to choose freely the DR service they want [*22*].

The reserves markets and the balancing market are operated by the system operator "FINGRID" and accept demand side resources that are aggregated to meet the minimum requirements for response regarding resource size, etc. Depending on the type of the reserve market, the minimum size varies from 0.1 to 10 MW and the maximum response latency from seconds to 15 minutes [*40*]. The amount of dynamic DR in Finland is divided as follows: day ahead (Elspot: 200 – 600 MW), an intra-day (Elbas) energy markets offered by electricity exchange, balancing power market (100 – 300 MW), frequency controlled disturbance reserve (70 MW), fast disturbance reserve (354 MW) and power reserve (40 MW). The balancing and frequency controlled reserve power markets are offered by the main grid company, "FINGRID" [*22*], [*40*]. More details can been seen in Table 3.

The "FINGRID" has three main aggregators, namely, SEAM, Energiakolmio and There Corporation [*41*]. SEAM provides such customers covered by the DR services, in combination with the other end-use energy management service. Energiakolmio provides energy market services, such as, DR aggregation for balance management, etc. There Corporation provides technology for the Home Energy System (residential DR) and the dynamic pricing control.

Table 3: DR programs in Finland [*40*].

Market Place	Type of contract	Min. size (MW)	Price level
Frequency controlled normal operation reserve	• Yearly and hourly markets	0.1	• 15.8 €/MWh (yearly market) + price of electricity
Frequency controlled disturbance reserve		1	• 4.03 €/MWh (yearly market)
Frequency controlled disturbance reserve (on-off-model)	• Long-term contract	10	• ~0.5 €/MWh + 580 €/MWh + activation fee of 580 €/MW
Automatic frequency regulating reserve	• Hourly market	5	• Hourly market + energy price
Balancing power market		10	• Market price
Fast disturbance reserve	• Long-term contract		• ~0.5 €/MWh + 580 €/MWh
Elspot	• Hourly market	0.1	• Market price
Elbas			
Strategic reserves	• Long-term contract	10	-

3.3. Progress vs Status Quo

In Finland much of the generation is based on nuclear and thermal load, boosting the CHP. This last resource (CHP), accounts 45% of the total installed generation capacity [*42*]. The currently installed capacity of RES corresponds to 20% of total generated installed capacity. Small hydro (pumping excluded) has the highest share in RES, near 18% in total electricity supply. Wind and solar have the lowest share in DG, 1.3% and 0.01%, respectively [*42*]. The installed wind capacity is close to 400 MW, however an increase up to 2,500 MW has been targeted for year 2020. The main reason for this increase, is Finland's FIT system introduced in 2011, available for wind power, bio-gas and wood-driven power capacity [*43*]. A significant amount of controllable loads are available, through the use of smart meters [*44*].

4. Concluding remarks

Denmark, with its high integration and promotion of renewable energy can bring to a consumer more benefits than Finland. However, these benefits have a considerable influence in the energy costs for the consumer due to the Public Service Obligation tax.

Finland has an energy market well developed for DR integration and thus can provide flexible consumers with fewer advantages than Denmark. Also, energy costs for consumers in Finland are lower than in Denmark, mainly due to the primary energy sources considered. In this way, an equal characteristic consumer located in Denmark and Finland, can spend more in Denmark than in Finland in its consumer's bill. Denmark seems to be more developed and focused on the benefits of smart grid technologies than Finland, that isn't focused on renewable energy progress.

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Simulation of consumers and markets towards real time demand response
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Current status and new business models for electric vehicles demand response design in smart grids

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Abstract

Global electric vehicles sales increased about 10 times from 2011, reaching more than 1 million vehicles in roads by 2015. This number is very likely to increase at a steady pace as more models are made available and battery technology improves and costs decrease. It is recognized that the electric vehicles mass integration will imply more complexity to the operation and planning tasks of power systems, but also allow additional opportunities. Indeed, demand response can play a major role to integrate electric vehicles in the future smart grid. This paper discusses the current initiatives from the retailing business in Portugal, Spain and Germany to deal with electric vehicles integration and discusses some new demand response models shaped for the smart grid that can be the new business model of tomorrow energy providers. Currently, the electric vehicles demand response measures adopted by the industry are very limited, mostly offering time of use tariffs with a discount rate.

Keywords: demand response, electric vehicle, smart grid, tariffs

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1. Introduction

During the last years, a growing number of Smart Grid (SG) initiatives has been rolled out. In fact, 459 SG projects have been funded in Europe from 2002 to 2014, with a total investment of €3.15 billion investments, both public and private [*1*]. Several demonstration and deployment projects have started in this field and rollout of smart metering is increasing over time. Research and development activities in some related topics, such as aggregation models and vehicle-to-grid concepts are also going on [*2*,*3*]. In the meantime, Electric Vehicles (EVs) sales have been steadily increasing since 2011, with the pure electrics capturing 62% of sales by mid-September 2015 [*4*]. In Norway the market share astoundingly surpassed 22% by the end of 2015, increasing from 6% in 2013 [*5*]. In Germany the acceptance is being much slower with only 0.73% market share by 2015. In the United States, EVs stock reached 410,000 by December of 2015, but still half behind the 2015 target of one million EVs announced some years ago [*6*]. Portugal is ahead of Spain regarding EV transition, but these two countries currently do not have significant market share and EVs stock. Nevertheless, the charging infrastructure to support EVs adoption has been growing dramatically with projections suggesting more than 12 million public charging points in the year of 2020 [*7*]. The mass integration of EVs has been planned and their integration implies more complexity to the operation and planning tasks of power systems, but also enables significant benefits [*8–10*].

In this context Demand Response (DR) shaped for EVs is a big opportunity that the power industry cannot miss. The DR programs can be classified in price-based DR, incentive-based DR, and emergency DR, among others [*9*]. DR refers to *"changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized"* [*11*]. According to [*12*] vehicles are parked more than 90% of the time during a day, thus they can be available to serve as a storing device to the grid. Indeed, EVs are represent additional loads which are well suited for DR participation as their demand can be shifted or reduced through incentive or price-based schemes. In addition, EVs charge and discharge can be controlled using optimization algorithms and control means, though these imply higher complexity and increased infrastructure costs.

Currently, some initiatives to avoid high peak demand have been started in the retailing sector. These initiatives mainly consist in introducing some special tariffs targeting EV customers. In this paper, some of them devised by companies in Portugal, Spain and Germany are briefly described. These business models seem functional and rapidly available in the short-term horizon but are very limited to attain the full potential of SG deployment. Therefore, immediate rethinking is urged and new business models must be developed to ensure the successful EVs' integration in the SG.

DREAM-GO is a European Union (EU) funded project (H2020-MSCA-RISE-2014) that aims to leverage the state of the art regarding DR implementation. The project consists in a transcontinental cooperation and knowledge sharing between EU partners and the United States. Regarding the work developed so far, it is believed that DR response can play a significant role to integrate EVs in the existent grid without deep modifications. This paper discusses some possible ways to implement DR for EVs in the context of SGs.

After this introductory section, the paper is structured as follows: section 2 presents a brief overview of the current status regarding EVs DR implementation, section 3 presents the DR business models envisaged for the future SG, and, finally, section 4 draws up the main conclusions of the work.

2. Current Status

EVs will be responsible for a significant part of the energy bill in the near future. This section discusses the EV household impact and briefly describes the initiatives of the retailing sectors in 3 countries: Portugal Spain and Germany.

2.1. EVs household impact

The shift from petrol-fueled transportation to electric means will carry significant shifting of money transactions from petrol stations directly to the electricity supplier. It is important to understand how EVs charging will impact the energy bill and how this energy will be consumed. Fig. 1 shows a daily curve demand for a Portuguese household with 4 occupants in the winter[1]. We are considering that the family living in this house owns one EV (Renault Zoe), which travels 80 km per day in average. The EV plugs and starts charging immediately after arriving home by 7 p.m. to fulfill the needs for its daily journey at 3 kW/h charge rate.

It can be seen in the load curve that the EV arrives around 19h and starts charging immediately without any control. The total amount of charging is 11 kWh for a daily commute of 80 km. The battery is fully charged around midnight. The EV contributes to increase the winter household consumption by 64%. By contrast, in the summer the EV contributes to increase the same household consumption by 220%.

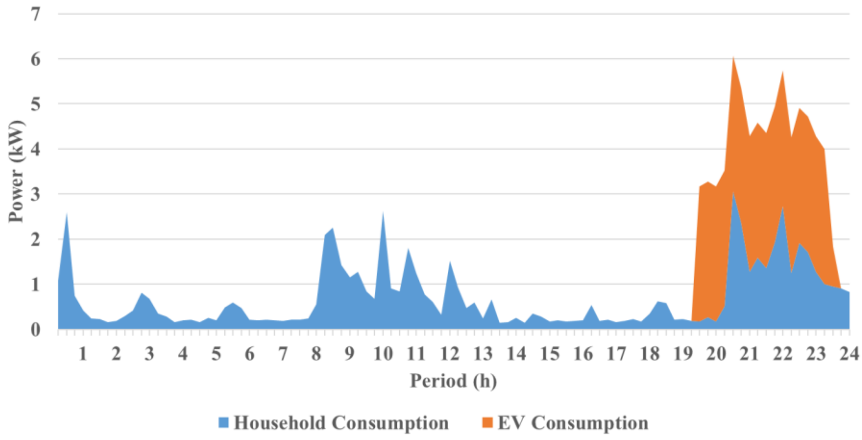

Fig. 1: Household winter consumption with uncontrolled EV charging.

By the above example, it is easy to understand that the EV adds a significant portion of the household load demand. The peak load reaches 2 times the original value. In fact, with the EV the peak power reaches 6 kW instead of 3 kW without the EV. The situation would be worse if the household had 2 EVs.

2.2. Retailing activity initiatives

Currently, few initiatives are offered by the retailers to motivate the EV adoption and differentiate the EVs demand. EDP Comercial is the only retailer in Portugal to offer a differentiated tariff. EDP Comercial is offering a 400 EUR discount to those who buy an EV from their partners [13]. The discount is done on a monthly basis, i.e. 40 EUR/month during 10 months. EDP claims that the discount is equivalent to 15.000 km.

[1] The household dataset, in what regards the load demand, excluding the EV charging, can be obtained in http://sites.ieee.org/psace-idma/data-sets/

In addition to that discount, EDP Comercial launched a special time-of-use based tariff, named energy2move, for those who own an EV. The energy2move is a bi-tariff with 10% discount during the night (10 p.m. to 8a.m.) for the daily option and 1% discount in the remaining periods. A weekly option[2] is also available. The discount rate is also applied to the basic monthly fee. In the case of the tri-tariff option the discount rate is 7% in the remaining periods. However, the tri-tariff is only available for contracts between 27.6 kVA and 41.4 kVA. The energy2move has not a single-tariff option. Instead, this retailer is motivating his customers to shift EV load to economic periods using bi-tariff (or tri-tariff) with some discount. The economic periods are mostly during the night.

In Spain an hourly pricing scheme is in place, which applies for all the Spanish territory regardless of the time-zone, known as voluntary price small consumer (PVPC). There are three types of tariffs: default, 2 periods and electric vehicle. Active energy invoicing term in €/kWh of PVPC for tariffs 2.0 A (default tariff), 2.0 DHA (2 periods tariff) and 2.0 DHS (EV), are established in section 2 a) of the Article 8 of the Royal Decree 216/2014. The royal decree states the calculation methodology of PVPC of electrical power and its legal and contracting system [*14*]. PVPC includes several terms, namely day-ahead market price, ancillary services, distribution and transmission tariff, capacity payment, interruptible service and operation, and maintenance fees.

Fig. 2 shows the PVPC prices along an entire day (26th April 2016) for the three mentioned tariffs. Those prices do not include taxes. The prices range for each period can be seen in the *xx* axis; in green color the hours with prices lower or equal than 0.10 €/kWh, in yellow color for prices between 0.10 €/kWh and 0.15 €/kWh and in orange color for prices higher than 0.15 €/kWh (which did not happen in the considered day). For the 26th April 2016 most of the periods are in the green price range. The EV tariff is cheaper at night, namely between 0 a.m. and 12p.m. The customers can freely choose PVPC. Retailers are not allowed to charge the customer higher prices than the PVPC in this mode [*15*].

Fig. 2: Active energy invoicing price in Spain using PVPC (26-04-2016) [*15*].

In Germany, despite high electricity prices (>0.25 €/kWh) for the typical household, some utilities are introducing benefits for EV owners by proposing different tariffs. The e-mobility night tariff proposed by Litchblick, a German utility, allows customers to charge their cars at lower rates during the night [*16*]. Other retailers such as Polarstern energie are offering night tariff reductions for EV charging as well [*17*]. Moreover, Litchblick is studying an aggregator

[2] Bi-tariff low price periods:
Summer week cycle: Monday-Friday: 0h-7h; Saturday: 14h-20h and 22h-9h; Sunday: 24h.
Winter week cycle: Monday-Friday: 0h-7h; Saturday: 13h-18h30 and 22h-9h3; Sunday: 24h.

model for small generation and controllable loads. EVs, heat pumps, and overnight electric heating systems can all function as controllable consumption equipment [*16*]. This German utility believes that a household's power rate could be 30 percent lower when controllable consumption is correctly scheduled, and the cost of charging EV could drop by up to 200 EUR annually.

A few players in the retailing activity are introducing a variety of appealing schemes for the EVs end-users. However, it is fair to recognize that these schemes are based on discount rates and still very limited, not adequately adapted for the future smart grid. Nevertheless, the paradigm shift is occurring and eventually more advanced models have to be developed and implemented in practice. In the following section some innovative models are discussed, which could be increasingly viable with proper charging, communication and IT infrastructure.

3. Demand response business models for the SG

This section discusses some DR models shaped for EVs. These business models envisage a SG context, and therefore, smart metering and other important infrastructure is assumed to be in place. The presented programs include incentive-based programs – smart charging, V2G, trip shifting, trip reduced – and one optimal pricing DR model (price-based). Fig. 3 represents the mentioned DR programs and the necessary information flow.

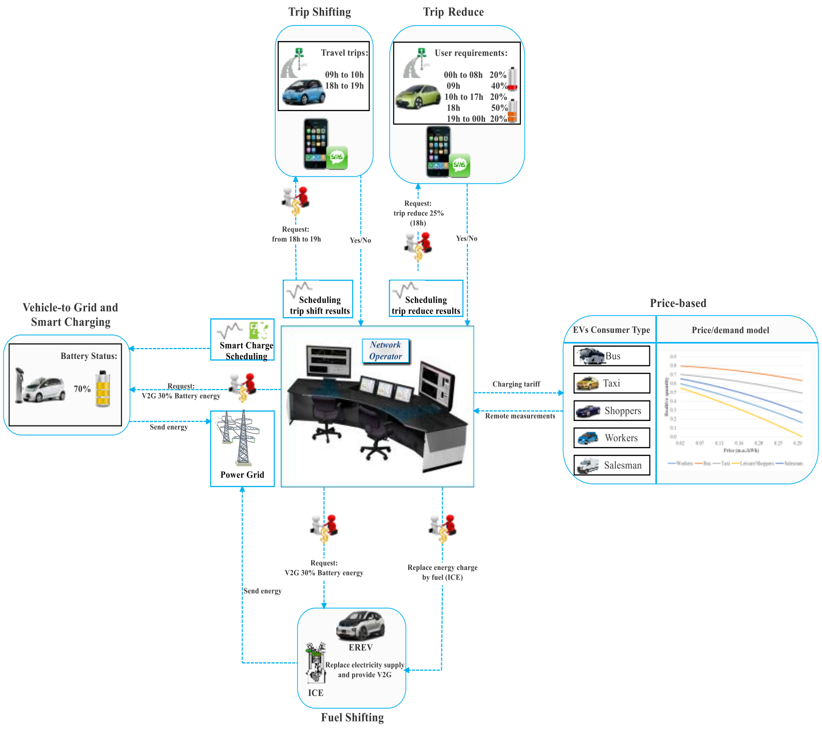

Fig. 3: Representation of the DR programs for EVs

3.1. Smart charging and vehicle-to-grid

EVs can provide power to the grid while they are connected to it, which is usually referred as Vehicle-to-Grid (V2G) [*18*]. The control approach requires a control connection for communication with the grid operator and a meter sensor to indicate the battery state in each moment [*19*]. The Society of Automotive Engineers, known as SAE, establishes a series of requirements and specifications for communication between plug-in vehicles and the electric power grid, for energy transfer to and from the grid in the standard SAE J2847/1 "Communication between Plug-in Vehicles and the Utility Grid" [*20*]. The International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) are also developing a similar series of standards known as ISO/IEC 15118 "Road vehicles -- Vehicle to grid communication interface" [*21*].

The smart charging and V2G approaches are effective types of DR resources use in the context of EV management. The EV charging can be effectively controlled while reducing operation costs and network problems, while still maintaining the comfort of the users. The drawback of V2G and smart charging is the high complexity and high capital costs of the infrastructure. Nevertheless, aggregators may convince users to shift from uncontrolled charging to smart charging by financial incentives and convenience of charging, e.g. with smart charging, the user could benefit from discounted flat tariffs

3.2. Fuel shifting

Fuel shifting is a special DR program, specifically proposed to target a particular kind of EVs, the Extended Range Electric Vehicles (EREV). These vehicles have an Internal Combustion Engine (ICE) that can charge the battery when a threshold limit is reached. This greatly increases the travelling range, while mitigating the user’s range anxiety. Examples of EREVs are the Chevrolet Volt, Opel Ampera and BMW i3. The fuel shifting has 2 variants. One is to incentivize customers to leave the charging point (home/workplace) even if the minimum amount of state of charge was not satisfied (soft constraint). The customer in turn receives an incentive to cover the fuel costs that may be needed to cover the trips not satisfied by the electric energy supply. The grid in turn can mitigate and/or avoid network problems and costs and reduce the peak demand. The other variant of fuel shifting DR is that these cars can participate in V2G services, namely in extreme situations, and use the ICE more than intended.

3.3. Trip reduce

The trip reduce is an incentive-based DR program to provide the aggregator with a flexible resource, in which users can participate by agreeing to reduce the EVs’ charge requirements. This program enables EVs’ owners to get a financial incentive by agreeing to reduce their trip energy requirements and consequently the minimum battery level requirements. The participation of users in this DR program can be performed as follows: users should sign up to the DR trip reduce program and notify the aggregator about the maximum amount they are willing to reduce. With this information the aggregator runs a daily routine optimization. In the day-ahead, an initial optimization is made assuming that EVs with contracted DR program will participate. With the first-round optimization results, it is possible to identify the EVs that are scheduled to participate in the event and notify the respective users. Then, the notified users should confirm their participation within a defined time period. With the confirmation responses, the optimization program can perform a rescheduling with the updated information, fixing the users with confirmed participation and making the required adjustments. Users that do not confirm their participation within the requested time period are excluded from the DR event. A penalty scheme can be implemented for the EV users who confirmed the participation and withdraw it later.

3.4. Trip shifting

The trip shifting program is an incentive DR program similar to the trip reduce. However, this DR program enables EVs' users to provide a list of flexible departure periods. This could be implemented in a similar way to the DR trip reduce program, i.e. the users sign up and setup their profiles and definitions by using an internet-based app. The DR program specifically enables the aggregator to shift EVs charging, which may help to reduce operational costs and alleviate network contingencies. The shifting is limited to the alternatives that users introduce, thus limiting the computational complexity of the optimization process. The users' participation in the DR shifting program would be similar to the process described for the trip reduce program. In face of the users positive replies to participate in the DR shifting event after being notified, the optimization program should perform a rescheduling with the updated information.

3.5. Price-based optimal pricing

The price-based DR strategy consists in defining the price that the EV owner pays to the aggregator, while ultimately changing his charging behavior. In this case it is assumed that the EV charging process cannot be controlled and consequently smart charging and V2G algorithms are not possible.

The advantage of this approach is that it does not require an advanced and complex infrastructure, such as the previous DR programs. Therefore, the price is the relationship for indirectly controlling the timing and amount of charging. The proposed price-based DR assumes that there is a correlation between the quantity of charging and the price to be paid for it. Also, the decision-maker can describe the behavior of its customers and the correlation between the quantity that the owners of EVs usually charge and the price they pay. The EVs can be classified according to several groups of consumers as suggested in Fig. 4, which shows an example of price elasticity curves for five groups of EVs' consumers.

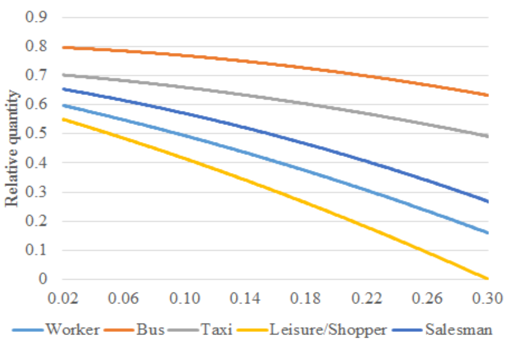

Fig. 4: Elasticity curves for distinct groups of EVs consumers.

A relative quantity of 1 means that the EV would charge whenever it would be possible, while a relative quantity of 0 means that the customer is not willing to charge at all. The represented data can be obtained using historical data or surveying consumers.

The price is directly correlated with the quantity that the user is willing to charge. Looking at Fig. 4 we can conclude that the workers group is willing to charge more than the leisure group even if the price is higher, whereas the bus fleet group is willing to pay and charge more than the other two groups due to its higher responsibilities towards third parties.

4. Conclusions

This paper briefly presents the current status of the retailing sector in some countries of Europe, namely Portugal, Spain and Germany, in what regards electric vehicles charging tariffs. Time of use tariffs are being offered by a few energy provider utilities for this purpose. In some cases, tariffs intended for general use have some discount when the customer owns an EV. Flat rates with discount or without discount are not proposed by any of the analyzed energy providers. Instead, tariffs propose a range of economic periods for EV charging.

EVs will account for a significant part of the consumers' energy bill in the future, both in costs and energy terms. With the mass integration of EVs, sophisticated demand response models are urged. This paper discussed incentive-based models and a price-based model to deal with a large number of EVs in the grid. Those DR programs are shaped for EVs and can be offered in the future, independently or combined with the already established agreement/contract between the EV user and the energy provider.

Energy aggregators are well suited entities to take full advantage of the opportunities offered by these DR programs in combination with other tasks they already perform. Therefore, implementing those measures may allow to postpone network investments, reduce operation costs, increase competition in the retailing activity, provide some benefits to customers, while successfully tackling the advent of EVs.

Acknowledgements

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Simulation of consumers and markets towards real time demand response
First DREAM-GO Workshop

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Price-based and Incentive-based Framework of Demand Response in Portugal

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Abstract

Demand Response is a flexibility tool that can provide several benefits to the electric power system's operation, namely by providing ancillary services. Although several countries have similar active consumer approaches, the truth is that these methodologies are not always clear or transparent to outsiders, and even sometimes to locals (difficult interpretation of legislation). In this way, the present paper explains Portuguese price-based and incentive-based demand response strategies, and proceed with an analysis and evaluation of the current stage of their implementation. Although the programs exist and are available, their actual use are still very limited.

Keywords: demand response, energy markets, energy policies, smart grid

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1. Introduction

In Portugal, Demand Response (DR) strategies are more focused in price-based programs than in incentive-based programs. The price-based ones include market stimulations that motivate the consumer to reduce consumption voluntarily and based on its personal interests, according to the electricity price. In this way, these programs often reflect a decrease of energy costs, or the gain of benefits when in comparison with other consumers. Incentive-based programs reflect the interest of third-party entities in the consumption reduction (e.g. ancillary services performed by a transmission system operator), and implies monetary remuneration [*1*]. When considering ancillary services, one realizes the huge potential of demand response for energy systems and their usefulness for the system operator, since the capability of modifying load can be determinant in emergency and security activities [*1*]. Other European countries have developed DR programs, and are today important success references regarding the benefits of DR implementation [*2*].

In the next section, the characteristics of price-based and incentive-based programs implemented in Portugal are presented. The next section is therefore divided in two subchapters: price-based and incentive-based programs.

2. Price-based DR Programs

Currently, in Portugal, electricity prices are divided into two seasonal periods for all consumers. Time differentiation goes even further when the consumer can choose to consider to have its days be equal (daily cycle – only for consumers connected to low voltage) or different (weekly cycle), in what concerns the tariffs and hours applied. Hours can be included from one to four periods. Fig. 1 presents the tariffs decomposition for the Portuguese scenario. In this way, one can see the general composition defined by the regulator (Entidade Reguladora dos Serviços Energéticos – ERSE) concerning the implementation of price-based active consumer's programs.

As one can see by Fig. 1, the consumer has several options to contract supply and can reduce its energy costs by choosing the program which grants him lower tariffs in the times of his highest consumption, or reduce load in times where the price is higher. The single tariff option is the most used by consumers, since the same price is applied across all periods and days. The double tariff scheme considers two tariffs, that are applied to on-peak (peak plus mid-peak periods) and off-peak periods (valley and super valley periods). In this way, there are several successive hours, especially at night, where the energy price is considerably lower. In the triple tariff scheme, a tariff is applied in the peak, mid-peak, and off-peak periods [*3*], [*4*].

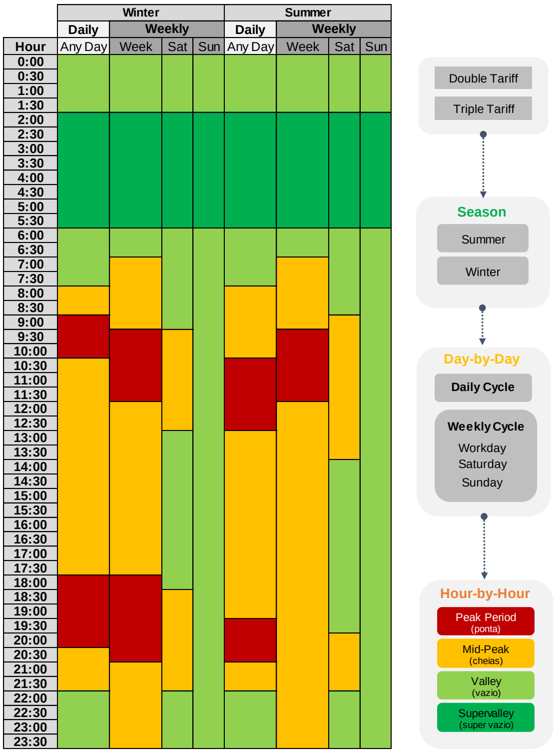

Fig. 1: Tariff decomposition considering winter and summer schedule, daily and weekly, in Portugal.

Fig. 1 also presents the different types of schedule available for consumers, namely considering, season, day, and hour. As one can see, peak periods are the minority amongst other periods as it would be expected, followed by mid-peak periods that are more often, not only on week days but also on Saturdays. Finally, off-peak periods (valley and supervalley) complement the majority of a week schedule with occupancy on the nights of the week, Saturdays, and fully on Sundays. Having the schedule presented in Fig. 2, one can easily apply the tariffs from a supplier and perform a cost/benefit analysis according to a particular consumer situation.

3. Incentive-based DR programs

In Portugal, incentive-based programs are defined through government legislation with a common link with the Spanish regulation. Since Portugal belongs to the Iberian market, MIBEL, the Portuguese and Spanish legislation are harmonized between each other in order to facilitate the energy connections and communication amongst the two countries. In this way, Fig. 2 presents the timeline of incentive-based programs legislation publication, in Portugal [*5*]–[*13*].

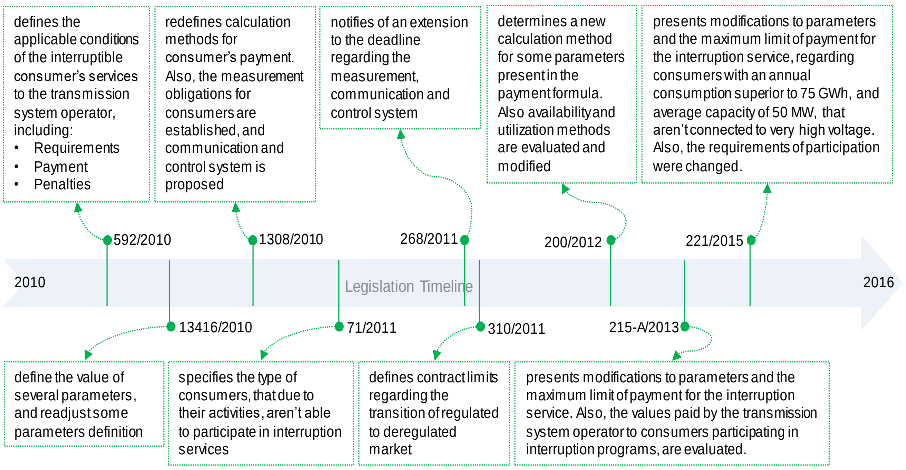

Fig. 2: Portugal's DR legislation timeline and respective features.

In Portugal, DR programs are defined by their type, notice time, maximum duration, number of periods allowed, and maximum duration per period. In this way, the following Table 1 presents the characteristics of Portuguese programs.

Table 1 shows that, per example for the first type of consumer, the transmission system operator can perform only one request per day, to a maximum of 5 per week. In each order the operator can have a maximum of 3 periods of time, each with a limit of 4 hours. This means each request will have a maximum duration of 12 hours. The transmission system operator has a limit of 120 hours of use for each consumer, per year. Finally, the operator needs to notify the consumer at least 2 hours before the actual interruption period [*5*]. Each reduction order sent by the operator must contain the following [*5*]:

- Type of reduction (1, ...,5);
- Number of periods for request at hand;
- For each period include:

- The beginning and finish time;
- Maximum load consumed value by the service provider (consumer).

Table 1: Portuguese DR programs characteristics.

<table>
<tr><th>Type</th><th>Notice time (min)</th><th>Max. requests per week</th><th>Max. requests per day</th><th># of Periods per request</th><th>Period duration (h)</th><th>Max. request duration (h)</th><th>Max. use (h/year)</th></tr>
<tr><td>1</td><td>120</td><td rowspan="5">5</td><td rowspan="5">1</td><td>3</td><td>4</td><td>12</td><td rowspan="5">120</td></tr>
<tr><td>2</td><td>120</td><td>2</td><td>4</td><td>8</td></tr>
<tr><td>3</td><td>60</td><td rowspan="3">1</td><td>3</td><td>3</td></tr>
<tr><td>4</td><td>5</td><td>2</td><td>2</td></tr>
<tr><td>5</td><td>0</td><td>1</td><td>1</td></tr>
</table>

Considering the type of reduction chosen, two options are presented where only reduction type 3 can have one or the other: model A (types 3, 4, and 5), or model A+B (types 1, 2, and 3). Table 2 presents the definitions that are to be considered in order to better understand the formulation [*5*]–[*13*].

Table 2: Portuguese DR programs definitions.

<table>
<tr><th>Parameter</th><th>Definition</th><th>Description</th><th>Unit</th></tr>
<tr><td>$P_{max\ a}$</td><td rowspan="3">Max. load after interruption</td><td rowspan="2">Maximum value of consumption that the consumer must have at the time of requested interruption</td><td rowspan="3">MW</td></tr>
<tr><td>$P_{max\ b}$</td></tr>
<tr><td>$P_{50\%}$</td><td>$P_{50\%} = P_{max\ b} + 0.5 \times (P_{cb} - P_{max\ b})$</td></tr>
<tr><td>P_{ca}</td><td rowspan="2">Consumption power</td><td rowspan="2">Maximum value of annual average power consumption, in the last three years of interruptible services, on peak periods</td><td rowspan="2">MW</td></tr>
<tr><td>P_{cb}</td></tr>
<tr><td>$P_{\text{int}\ a}$</td><td rowspan="2">Maximum interruptible power</td><td>Obtained from the formula $P_{\text{int}\ a} = P_{ca} - P_{max\ a}$</td><td rowspan="2">MW</td></tr>
<tr><td>$P_{\text{int}\ b}$</td><td>Obtained from the formula $P_{\text{int}\ b} = P_{cb} - P_{max\ b}$</td></tr>
<tr><td>Δ_a</td><td rowspan="2">Average monthly power difference quotient</td><td rowspan="2">Quotient of the difference between the monthly average power of the last year interruptible services in peak periods, the maximum load after interruption, and the maximum interruptible power</td><td rowspan="2">-</td></tr>
<tr><td>Δ_b</td></tr>
<tr><td>$FWpc$</td><td rowspan="2">Energy Quotient</td><td>Quotient between the total annual energy consumed and the annual energy consumed in peak and mid-peak periods</td><td rowspan="2">-</td></tr>
<tr><td>FWh</td><td>Quotient between the total annual energy consumed and the annual contracted power</td></tr>
<tr><td>μ</td><td rowspan="2">Factor</td><td>Monthly calculated according to the consumption made, and equal to:
FWpc ≥ 2.223, μ=1.9
2,223 >FWpc≥ 2.095, μ=1.75
2,095>FWpc ≥ 1.971, μ=1.55
1.971>FWpc ≥1.852, μ=1.30
FWpc<1.852, μ=1</td><td rowspan="2">-</td></tr>
<tr><td>φ</td><td>Monthly calculated according to the consumption made, and equal to:
FWh ≥ 5500, φ=1.4
5500>FWh ≥ 4500, φ=1.3
4500>FWh ≥ 3500, φ=1.2
FWh<3500, φ=1</td></tr>
</table>

Parameter	Definition	Description	Unit
pm	Average daily market price	Daily market price average for the hours where interruption was requested to the consumer	€/MWh
T_a	Sum of interruption hours per month	Sum of requested interruption hours in the month, for each reduction type	hours
T_b			

* The (a) and (b) indexes are related to reduction types 3, 4, 5, and 1, 2, respectively

After this parameter definition, one can now evaluate the consumer's payment formulation. In this way, model A is defined as follows:

$$rb_a = 2371.9 \times P_{\text{int}\,a} \times \Delta_a \times \mu \times \varphi \tag{1}$$

$$ra_a = 1.2 \times P_{\text{int}\,a} \times pm \times T_a \tag{2}$$

Where (1) represents the calculation of availability by the consumer over the course of the month (currently set at 18€/MWh maximum), i.e. actual use of DR (consumption reduction) isn't a part of this calculation, and (2), the actual reduction made by the consumer that is calculated and added to the previous payment – the operator is obligated to annually perform test reduction requests with a minimum duration of one hour, for 10% of the total interruption amount for that year. The model A+B is defined as follows:

$$rb_{ab} = rb_a + \left(1016.5 \times P_{\text{int}\,a} \times \Delta_b \times \mu \times \varphi\right) \tag{3}$$

$$ra_{ab} = ra_a + \left(1.1 \times P_{\text{int}\,a} \times pm \times T_b\right) \tag{4}$$

Where (3) represents the calculation of availability by the consumer over the course of the month, and (4) the actual reduction made by the consumer that is calculated and added to the previous payment. The requirements needed to participate in Portuguese DR programs, consider several features of the consumers and is mostly directed to the load consumption and capacity of the consumer. The following describe these features [*5*]:

- Connection to medium, high, or very high voltage;
- Minimum load reduction of 4 MW;
- Install a frequency relay that operates within a frequency interval determined by the transmission system operator – Type 5 reduction;
- Install the required measurement, registry, and control equipment;
- If the operator wishes to establish a contract, and if in the last three years of interruptible load service, the consumer hasn't failed to deliver twice or more times;
- The activity of the consumer isn't one of the activities considered essential, i.e. the operator can't contract with [*7*]:
    - Water, electricity, or natural gas suppliers;
    - Post office or telecommunication companies;
    - Medical associations (hospitals, clinics);
    - Security or national defence organizations (fireman, police);
    - Public transportation sector (including transport security);
    - Public service organizations related to solid or water waste.

The penalties for failure to comply with the amount requested, implies the following:

- If the first time in the last 12 months, the penalty results in a monetary fine equal to 4 months of availability remuneration;
- If the second time in the last 12 months, the penalty results in a monetary fine equal to 12 months of availability remuneration;
- If two or more failures have occurred in the last 12 months, the penalty results in a monetary fine equal to 12 months of availability remuneration, and the cancellation of the contract with the consumer.

As one can see, the requirements imposed by the Portuguese legislation regarding the participation of consumers in interruptible services, is mostly targeted for large consumers of electricity (e.g. voltage level, minimum interruptible amount). In this way, the program isn't embracing other classes of consumers that are more common than the ones considered for the DR program, namely, households, apartments, office buildings, small commerce facilities, amongst others. By limiting the DR program to a relatively small class of consumers, reduces the amount of interruptible load amount available for the transmission system operator.

4. Analysis of Incentive-based DR in Portugal

In the present chapter, one performs the analysis of the current status of DR implementation in Portugal, regarding incentive-based programs. Table 3 represents the progress of incentive-based DR in Portugal, since 2013 [*14*]–[*16*].

Table 3: Incentive-based DR evolution.

Year	Model	# of Consumers	Interruptible Power (MW)	# of Reduction Orders	Payment for Availability (M€)	Payment for Use (M€)
2013	A	2	671	0	87.3	0
	A+B	47	653.3			
2014	A	2	705.2	0	101.9	0
	A+B	49	687.5			
2015	A	50	714.2	0	109.9	0
	A+B	2	696.4			

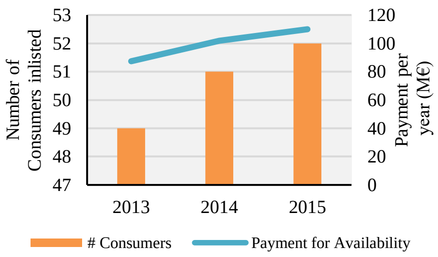

Fig. 3: Incentive DR: #consumers vs payment.

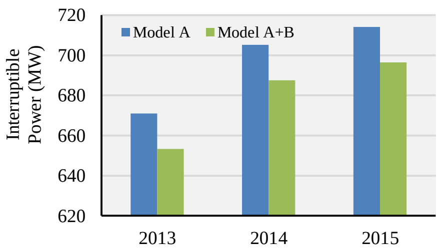

Fig. 4: Incentive DR: models A vs A+B

Focusing on the past year, according to [*16*] by the end of 2015, the transmission system operator (Redes Energéticas Nacionais – REN) had interruptible services agreement with 52 consumers. Of these consumer's interruptible capacity, 714.2 MW are from model A (reduction types 3, 4, and 5), while 696.4 MW are from model A+B (reduction types 1 and 2), thus obtaining a total available amount of 1.41 GW.

As one can see by the previous figures (Fig. 3 and Fig. 4) and Table 3, the progress of incentive-based DR is very lacking without a single request in 3 years. This shows that the costs to the transmission system operator, REN, are reflected only on the consumer's availability, spending millions of euros each year. In this way, these costs seem as unnecessary since the consumers aren't used at all, and thus an evaluation of the need of flexibility in Portugal should be considered in order to clarify if there's in fact a necessity for flexibility resources. Additionally, one can see that the transmission system operator hasn't fulfilled the legislation currently applied, since not even a test reduction request was made across the years or else not declared in the annual reports, which is obligated by law, as referred in [*6*].

5. Conclusions

The present work details the Portuguese legislation in what concerns the use of demand response measures, namely, the incentive-based and price-based programs available for consumers. Currently, price-based programs are made available by several entities (suppliers, retailers, amongst others) and therefore they are more common than incentive-based programs. Moreover, consumers connected to higher voltage levels (medium, high, and very high voltage) are metered with time differentiation, thus the tariffs used by these consumers have to be also time differentiated, namely, four time blocks (peak, mid-peak, valley, and supervalley).

Regarding incentive-based programs, they are only available for consumers connected to medium, high, and very high voltage networks. The results about incentive-based programs show that these aren't very used by the transmission system operator, in fact, not at all. The consumers with an established agreement are only paid for being available, since their activation throughout the years has never been made. This shows a huge loss in terms of DR potential and monetary funds that could have been used for other important network-related activities. In this way, Portuguese legislation needs to be improved and control mechanisms should be implemented, in order to enable a more transparent, attractive, and fair remuneration system for DR integration.

Acknowledgements.

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Real-Time Power and Intelligent Systems (RTPIS) Studies at Clemson University

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Abstract

Real-Time Power and Intelligent Systems (RTPIS) Laboratory is a premier world class research, education and innovation ecosystem laboratory for smart grid technologies. Research areas studied include, but not limited to, adaptive devices, circuits and systems, computational methods, cyber-physical systems, hardware-in-the-loop (HIL) studies, high performance computing platforms, intelligent systems, micro-grids, nano-grids, plug-in electric and hybrid vehicles, power system stability, control and operations, renewable energy, real-time large power system simulation and operations, sensor networks, signal processing, synchrophasors, wide area systems.

Keywords: smart grids, communication technologies, intelligent network, real-time applications

1. Introduction

With about 200 Clemson's real-time grid simulation laboratory is equipped with the RTDS™ real-time digital simulators, multi-vendor phasor measurement units (PMUs), phasor data concentrators, security gateways for PMUs and advanced metering infrastructure. The modified IEEE 68 bus benchmark system with FACTS/HVDC, wind farms, PV plants, energy storage systems and plug-inn electric vehicles can be simulated on the RTDS platform using very detailed models. Large power system simulation in real-time is possible with the use of a hybrid platform – RTDS/Clemson's Palmetto cluster.

The Real-Time Power and Intelligent Systems Laboratory is equipped seven racks of real-time digital simulators (RTDS) and can model the IEEE 118 bus/300 bus power system and PMUs.

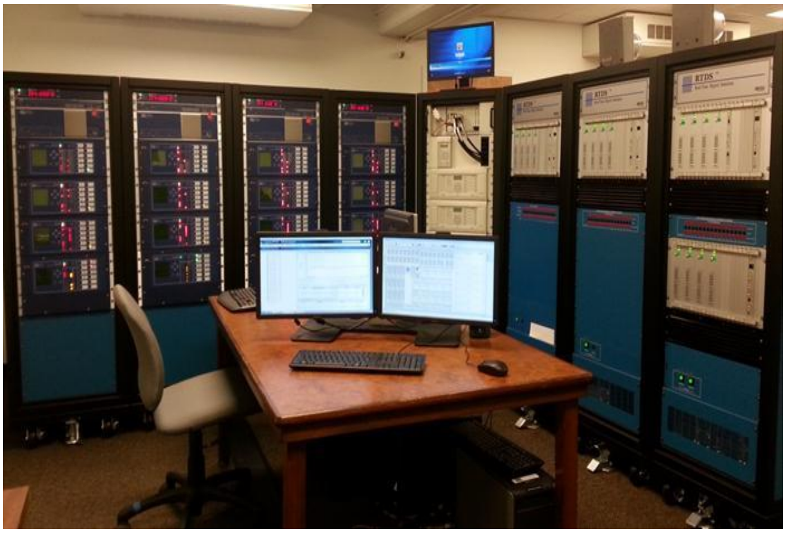


Fig. 1: RTDS and PMU Capability at the RTPIS Lab in Clemson University (Sept. 2014).

Currently, the lab is equipped with DSPs, FPGAs, synchronous generators, active filters, power amplifiers, digital scopes, signal generators and several high speed workstations.

In addition, the laboratory is equipped with sixteen physical PMU hardware from SEL. Some PMUs are built in-house and others are simulated on RSCAD software. We have enough PMUs (hardware and software) to simulate large amounts of PMU data.

The lab is also equipped with several simulation software packages including MATLAB, SIMULINK, SimPowerSystems, PSCAD, DIgSILENT, PowerWorld, RSCAD and FORTRAN. The RTPIS lab activities include prototyping intelligent controllers for generator excitation systems, FACTS devices, HVDC systems, wind farms, solar farms, micro-grids, electric ship systems, wide monitoring and control of power systems, and testing on the real time simulators.

A unique research and rapid prototyping laboratory for real-time situational intelligence and intelligent control technologies is developed at Clemson. Algorithms and methods for real-time situational awareness and intelligence, and visualizations for control centers are developed using in-house developed and third party software. The laboratory is focused on applications for transmission system, distribution and microgrid control center operations. The control center has workstations for four system operators besides the large front displays. Many of the applications are parallelized and implemented on Clemson Palmetto cluster using the dedicated high-speed fiber optic connection between Riggs Hall and the datacenter, about ten miles apart.

This laboratory (shown below) is the integration of the RTPIS lab capabilities (RTDS + microgrid + control center) with the Clemson Palmetto Cluster to carry out high-speed big data analysis. The control room shown in Fig. 2 has been developed and undergoing regular software updates. The visualization software for the control center is provided by utility vendors and also developed in-house by Dr. Venayagamoorthy's team.

Fig. 2: Situational Intelligence Laboratory at CU-RTPIS.

The 100kW micro-grid under development in Clemson is shown in Fig. 3. The micro-grid is to be equipped with a cyber layer. Measurements from the hardware components are to be taken using synchronized devices such as phasor measurement units (PMUs), micro-PMUs and smart meters. The RTPIS lab is equipped with PMUs and smart meters (Figs. 4 and 5).

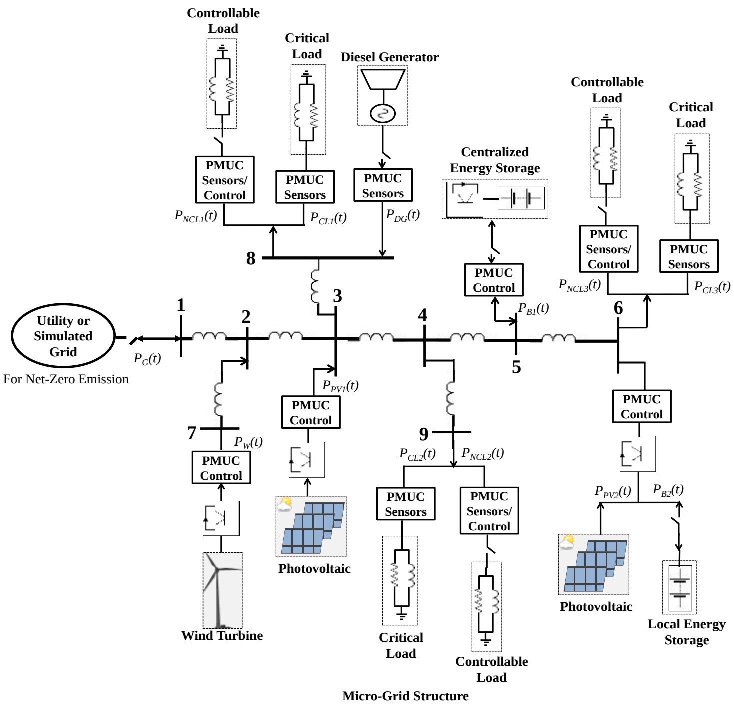


Fig. 3: 100kW micro-grid laboratory under development at Clemson University (under development).

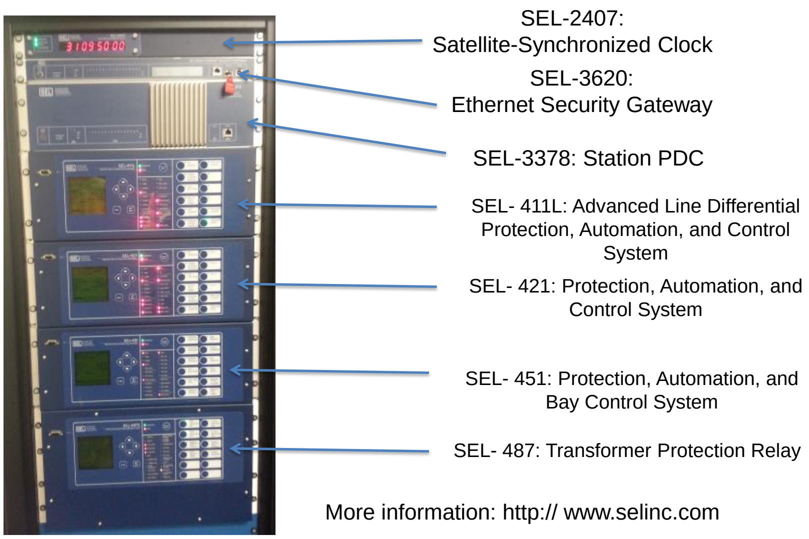


Fig. 4: Phasor Measurement Unit Rack – Four PMUs.

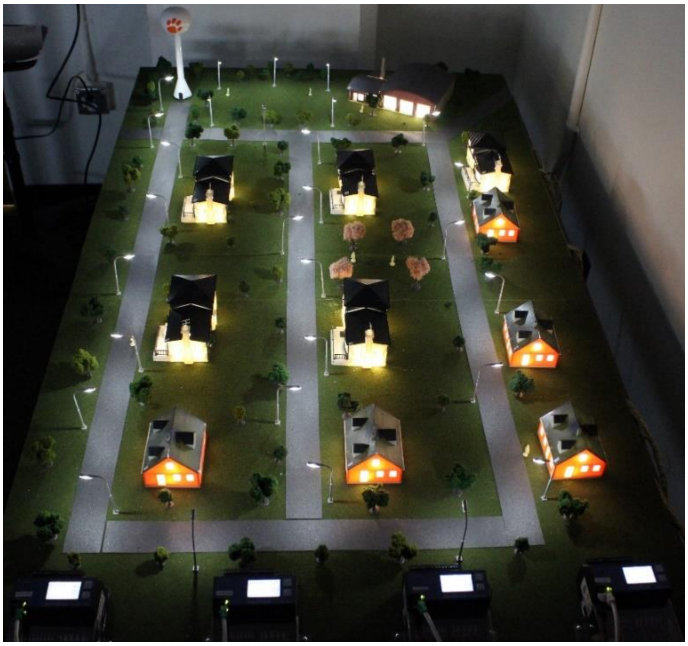
(a) (b)

Fig. 5: Smart Meters (a) Itron Meters (b).

2. The RTPIS Lab Environment

The RTPIS Lab smart neighborhood for demand response management studies is shown in Fig. 6. The loads for the various customers have emulated through a load box built at the RTPIS Lab.

(a)



(b)

Fig. 6 (a) RTPIS Lab Smart neighborhood (b) Smart neighborhood operation at 100% load

Selected Current Projects at the RTPIS Laboratory

- An Intelligent Restoration System for a Self-healing Smart Grid (IRS-SG) Clemson University's Synchrophasor Engineering Education Program (CU-Sheep).
- Computational Intelligence Methods for Dynamic Stochastic Optimization of Smart Grid Operation with High Penetration of Renewable Energy.
- Dynamic Energy Management System (DEMS) for a Smart Micro-Grid.
- Research Alliance: Situational Intelligence for Smart Grid Optimization and Intelligent Control.
- Scalable Intelligent Power Monitoring and Optimal Control of Distributed Energy Systems Using Adaptive Critics.

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Energy Dynamic Platform as Enabler for Future Smart Grids

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Abstract

Even though we have witnessed a huge development and deployment of WSN (Wireless Sensor Network) devoted to the energy efficiency business in the last years, these systems cannot always be effective and do not always mange to reach the goal of saving energy. This is partly due to the low compatibility among different systems, not enabling the communication with already existent building management systems, and due to the lack of an effective interface for data analysis. Another weakness is the absence of appropriate business models not allowing a good engagement and cooperative relation between end-users and energy suppliers. In this paper we describe an energy management platform, based in an IoT (Internet of Things) architecture, with a high interoperability and scalability level, and an intuitive and powerful user interface, as a powerful tool for energy saving analysis and decision taking.

Keywords: Energy management; IoT; Web Services; Graphical User Interface

1. Introduction

Smart Sensor Networks constitute a fundamental ingredient of the future smart networks and will lead the way towards the smart grid's extension to residential premises. Wireless Sensor Networks (WSN) enable the adoption of a set of dynamic energy management related strategies through sensing, gathering and disseminating information and data useful for the efficient operation of the power network. Additionally, the integration of WSN into the smart grid infrastructures provides innovative services and applications through which the active engagement of consumers is facilitated. Energy retailers are allowed access to real time energy information provided by the data gathered from the WSN, and can therefore provide useful signals to the end users as well as DR programs that can benefit both the consumers and the electricity power grid.

But with this rise of smart communication object deployment, a huge amount of data is being acquired and stored in powerful servers. This raw data needs to be converted in useful and manageable information in order to be useful for a suitable energy management. This requires a complete process of data collection, validation, processing, aggregation, visualization and management. A wide range of toolsets exist in the market today that allow for energy management, energy consumption calculation, consumers' active engagement in DR programs as well as end users' interaction and communication with the grid's operators, contributing this way towards the optimization of the grid's operation. These toolsets can be found in the form of company websites, mobile and web applications as well as other useful platforms that provide fully parameterized approaches for calculating energy. In the applications and tools offered in the market at this moment, appropriate business models are not provided, that could enable optimal energy requirements managements while making proper suggestions to end-users and engaging with their energy suppliers in the most active way. Another drawback of most of these system is lack of compatibility with installed legacy systems and other vendor's platforms.

2. Architecture Overview

VPS has developed an energy management platform to acquire, store, process, and display data in an understandable and convenient way. VPS's Platform has the following general characteristics:

(1) Capability to connect to smart meters and sensors from different vendors (energy meters, weather station, indoor temperature and relative humidity, lighting sensors, among others);

(2) Provide long term data storage;

(3) Provide processed data for data analysis;

(4) Provide valuable data analysis and forecast insights;

(5) Easy to use and intuitive interfaces for energy suppliers and end-users.

Fig. 1 represents VPS platform architecture which was developed using an IoT structured approach, consisting in the following modules: (1) Home Area Network/ Building Gateway, (2) Communication Module, (3) Data Processing Module, (4) API / Web services, (5) Data Analysis and Forecast, and (6) User interface.

This paper does not address Home Area Network module, focusing in turn in data handling and presentation modules like described in the following sections.

3. Communication Module

This module is responsible for retrieving raw data from sensor, such as temperature and meter readings, and for storing it in a dedicated database. Communicating with building gateways, or directly with smart meters, this module implements several protocols besides VPS proprietary protocols, assuring the openness of the solution. Some examples are:

- DLMS (Device Language Messaging Specification) - a protocol that is emerging as the worldwide standard of choice among smart meter designers for interoperability among all metering systems, including all energy types (electricity, gas, heat and water);
- OPC DA client (OPC Data Acquisition) - is the interoperability standard for Industrial Automation based on Microsoft COM and DCOM technologies;
- Modbus TCP – Modbus version over TCP/IP;
- Schneider Electric EcoStruxure Web Services– a communication service based on standards to interconnect Schneider Electric StruxureWare data concentrators;
- ODBC – generic database connection.

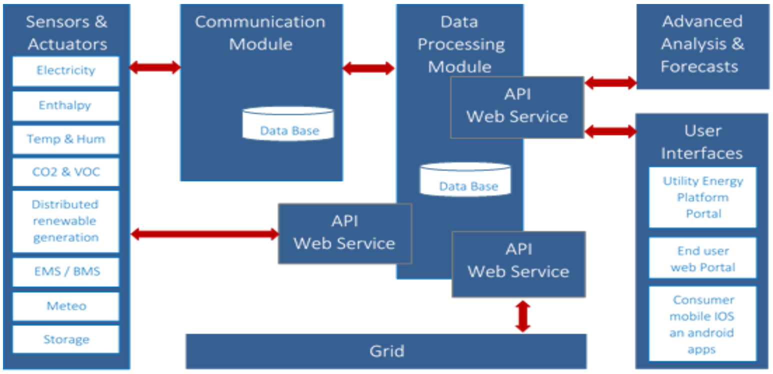

Fig. 1: System architecture.

4. Data Processing Module

After raw data is collected, it needs to be validated, processed and converted in useful and manageable information. This is done by Data Processing Module (DPM) which is responsible for receiving data from CM or from Web Service. This module processes and aggregates data, making operations such as unit conversion, format adaptation, tariff calculation, and distributing hourly and daily values. DPM as a data treatment layer offers, through another API – Web Service, a unified interface for other applications (User Interface, advanced analysis, forecasts).

5. REST API / Web Services

The Web Service modules allow the remote access and deliver data from sensors installed. This specific Web Service is based on RESTful Web Services, also known as REST APIs. This API is a default door to web applications data, providing a powerful yet simple tool to integrate different systems. This approach allows quick prototyping and interoperability capabilities between web applications and other systems in the physical world. This integration potential is enabled by the existing web infrastructure.

6. Data Analysis and Forecast

In order to enable the dynamic energy management and an active participation of consumers in demand, VPS' Dynamic Platform has efficient forecasting capabilities to adequately predict and estimate the energy consumption and renewable distributed production levels. Load forecasting for communities at building or micro-grid level is quite challenging due to constant dynamic changes that need to be considered and effectively handled in order to acquire accurate results.

The platform enables a two-way flow of data between suppliers and consumers in order to facilitate the power flow optimization in terms of economic efficiency, reliability and sustainability. This infrastructure permits the consumers and the micro-energy producers to take a more active role in the electricity market and the dynamic energy management. The dynamic energy platform depends critically on load and renewable production forecasting, which are delivered through intelligent methods and solutions for the real-time exploitation of large volumes of data generated by the vast amount of meters and sensors. Hence, robust data analytics, high performance computing, efficient data network management, and cloud computing techniques are critical towards the optimized operation of the platform.

Some data analysis methods implemented are:

- Traditional approaches such as historical data regression;
- Advanced approaches with hybrid methodologies that combine the best features of different methodologies depending on the application context, e.g. fuzzy inference systems and data filtering approaches, which analyze and find correlations in the historical data (e.g. using clustering methods), in order to select the most appropriate training data to feed the actual forecasting methods;
- Big data methodologies, such as incremental learning using the most recent captured data to update the forecasting learning models.

Fig. 2: Kisense web interface examples

7. User Interface

Kisense is the software solution used to cover the presentation tier of VPS's solution to provide the Utility Energy Platform Portal. It contains a set of visual modules which provide the operator the capability to access several features where we highlight the following ones:

A. *Total and disaggregated energy consumption;*

B. *Storage management;*

C. *Environment parameters;*

D. *Distributed renewable energy generation;*

E. *Remote control;*

F. *Forecast information;*

G. *Historic data visualization;*

H. *Consumptions normalization and benchmarking;*

I. *Alarm definition and visualization;*

8. Conclusions

VPS has developed a powerful yet simple to use energy management platform, which allows the distribution of large amounts of useful information and data regarding the energy consumption, storage, generation and behavior of end-users to the energy supplier portal in real-time. In this way multiple benefits and opportunities will arise not only for energy suppliers (balancing supply and demand, maximizing RES integration, reduce cost of energy prices, reduce BSUOS costs, etc.) or for the community (reduce power usage to reinforce energy efficiency), but also for the consumers who will now be in control of their energy consumption, therefore contributing to the optimization of the grid's operation in parallel with lowering their energy bills.

VPS' Dynamic Energy Platform offer innovative applications that goes beyond the current state of-the-art and delivers integrated end-user and energy supplier interfaces for new services and business models. Special focus is given to consumer empowerment and engagement providing also live energy data monitoring and active consumer interaction. Furthermore, attractive graphical web-based tools are included, concentrating on assisting the end-users, consumers and prosumers to be more dynamically engaged in the energy management and optimization of storage and local generation. These tools are designed to target at facilitating the overall energy management process, provide best decision support to buy energy in energy market and minimize BSUOS costs and can include also DR related activities to help balance the overall operation. This tools communicate alerts and notifications, as well as smart tips for reducing energy consumption without neglecting the consumer's comfort and estimations on multimodal motivators (cost, environment & security savings).

Acknowledgments

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