ENCOURAGE

Embedded iNtelligent COntrols for bUildings with Renewable generAtion and storaGE

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D5.1 – Operating scenarios and requirements for generation and storage

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Executive Summary

This task will initially focus on design of efficient control algorithms for pre-selected generation sources with a special emphasis on renewables. Among others, the algorithms will reflect the expected operation – i.e. if the generation source will be shared by multiple consumers, or it will have just one owner who will determine the preferred mode of operation. Critical decisions will be made on the level of intelligence to be embedded in the single source controller.

Individual generators will be characterised under different conditions to design realistic models, which will allow the development of efficient control algorithms. Control strategies for given renewable source will be designed while considering different forms of ownership and operating modes. The basic strategy will be tailored to the case when the generation source is owned and used exclusively by one building owner. More flexibility will be needed for a shared generation source, which is still primarily controlled by its owner, but it can be also used by others for purposes of the real-time supply demand balancing in the grid. Lastly, also the performance contracting models will be considered that assume the generation source is owned by an energy service company, while the home / building owner only provides site for given source.

In the first section, we concentrate on the generation of energy and how energy is stored. Energy is created from various sources such as mico-generation, Cogeneration and Photovoltaic energy. These are looked at and examined in this section. We look at how utility companies use this renewable energy and the methods which they used to store this energy.

The second section takes a look at the metering requirements for the platform to operate, it also look at the aggregation of the renewable energy available .Section two shows the importance and necessity of a monitoring system to be in place to monitor the ever changing generation of renewable energy. Different models of operation of use will also be looked at in this section.

In the third section we take a look the technologies and the way in which they communicate. We look at the different scenarios and the algorithms which may occur.

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The use of renewable energy increased greatly just after the first big oil crisis in the late seventies. At that time, economic issues were the most important factors, hence interest in such processes decreased when oil prices fell. The current resurgence of interest in the use of renewable energy is driven by the need to reduce the high environmental impact of fossil-based energy systems. The Encourage platform is designed to manage all the various parameters associated with this new technologies and how they fit within the Grid infrastructure. Harvesting energy on a large scale is undoubtedly one of the main challenges of our time. Future energy sustainability depends heavily on how the renewable energy problem is addressed in the next few decades.

Although in most power-generating systems, the main source of energy (the fuel) can be manipulated, this is not true for solar and wind energies. The main problems with these energy sources are cost and availability: wind and solar power are not always available where and when needed. Unlike conventional sources of electric power, these renewable sources are not “dispatchable” the power output cannot be controlled. Daily and seasonal effects and limited predictability result in intermittent generation. Smart grids promise to facilitate the integration of renewable energy and will provide other benefits as well.

Industry must overcome a number of technical issues to deliver renewable energy in significant quantities. Control is one of the key enabling technologies for the deployment of renewable energy systems. Solar and wind power require effective use of advanced control techniques. In addition, smart grids cannot be achieved without extensive use of control technologies at all levels.

Consumers will be made aware of the energy available and advised on their energy usage based on renewable sources available or forecasted energy generation.

The concentration on two forms of renewable energy – wind and solar – are now the primary driver to the future smart grid. Solar and wind power plants exhibit changing dynamics, non-linearity's, and uncertainties challenges that require advanced control strategies to solve effectively. The use of more efficient control strategies would not only increase the performance of these systems, but would increase the number of operational hours of solar and wind plants and thus reduce the cost per kilowatt-hour (KWh) produced.

Both wind and solar have tremendous potential for fulfilling the world's energy needs. In the case of wind, if conventional onshore wind turbines with 80-m towers were installed on 13% of the earth's surface, the estimated wind power that could be commercially viable is 72 terawatt (TW)[1]. That amounts to almost five times the global power consumption in all forms, which currently averages about 15 TW. With capacity that has tripled in the last five years, wind energy is the fastest growing energy source in the world. Using larger wind turbines to convert kinetic energy into electricity has significantly increased the average power output of a wind turbine unit; most major manufacturers have developed large turbines that produce 1.5 to 3.5 megawatts (MW) of electric power, even reaching 5 to 6 MW per turbine in some cases.

At the end of 2009, with 159.2 gigawatt (GW) of wind-powered generators worldwide, primarily grouped together to create small wind farms, the global collective capacity was 340 terawatt-hour (TWh) of energy annually, or 2% of global electric energy consumption. Several countries have achieved relatively high levels of wind power penetration: about 19% in Denmark, 14% in Spain and Portugal, and 7% in Germany and Ireland. Government subsidies have been a key factor in increasing wind power generation. These subsidies, in turn, have often been justified by the renewable portfolio standards (RPSs) that several countries have adopted and that require increasing the production of energy from renewable sources. In particular, RPSs generally obligate utilities to produce a specified fraction of their electricity from renewable energy. The European Union has a regionwide RPS of 20% by 2020; the United States of 20% by 2030, with different targets and years depending on the state (for example, 15% by 2025 in Arizona and 20% by 2020 in Colorado).[2]

[1] From: The Impact of Control Technology, T. Samad and A.M. Annaswamy (eds.), 2011. Available at www.ieeecss.org.

[2] http://ieeecss.org/sites/ieeecss.org/files/documents/IoCT-Part1-06RESG.pdf

Scope

Task 5.1 will develop control strategies for optimal operation of energy generation, consumption, and storage devices connected in a network. It will address the supply side of the system by developing appropriate monitoring and control concepts for local generation elements based either on conventional or renewable energy sources. Task 5.1 will produce a report summarizing all types of generation and storage equipment and related requirements on metering, communication and control technologies.

1. Generation Sources

1.1 Introduction

The ENCOURAGE project is focused on developing an embedded system which will address the optimization of energy through balancing generation and consumption. The present deliverable is concerned with “Monitoring and control of local generation”, thus this section presents advantages and constraints of local generation sources. The next sub-sections will focus on electricity generation methods like “Microgeneration” (mainly from renewable energies, photovoltaic and wind energy) or “Cogeneration”, explaining their principal characteristics, detailing their components and evaluating their influence in local network. Also “Storage” issues will be reviewed: storage systems, storage addressed to buildings and storage providers. Finally, utility company point of view about “demand usage of renewable, generation & storage” will be considered.

1.2 Renewable energy

According to forecast documents, in America ten Member States expect to exceed their national targets for renewable energy and five expect to need to use the Directive's cooperation mechanisms and reach their target by developing some renewable energy in another Member State or a third country. Whilst Member States expect to use the cooperation mechanisms for only a small amount of energy (around 2-3 mtoe), the forecast total production of renewable energy would actually exceed the 20% target and reach 20.3%. A summary is included below.[3]

1.3 Supporting Renewables

The generating capacity of renewable energy resources in the electric power sector is expected to increase by about 20% between now and 2030, with wind and solar sources roughly doubling during this period (see Table 4). As the grid penetration of wind and solar systems increases, the variability and uncertainty of supply will increase as well. A recent study by the Electric Reliability Council of Texas (ERCOT) showed that variability due to wind generation relative to the variability in load alone increased from about 6% to 19% due to expanding wind capacity from 5,000 MW to 15,000 MW. The study emphasized the importance of having a variety of quick-response non-spinning reserve options in the ancillary services market, including load curtailment. Demand response has a potentially significant role in supporting the growing role of renewables in the grid.

[3] http://ec.europa.eu/energy/renewables/transparency_platform/forecast_documents_en.htm

A case-in-point of the variability and uncertainty in renewable generation is the Stage 2 emergency that ERCOT faced on February 26, 2008. The event was triggered by a drop in wind generation from 1,700 MW to 300 MW because the wind died down. Simultaneously, demand increased by about 4,400 MW due to a drop in temperature and other non-wind power generators fell below their scheduled power production. Though a significant quantity of wind variability was anticipated (down to about 700 MW), the extreme drop coupled with the other factors made it an unusual event. The problem was addressed using demand response.

Specifically, 1,100 MW reduction within 10 minutes by calling upon interruptible loads of participating industrial customers. Auto-DR would allow a broader range of customers participating in a greater variety of demand response programs to respond to events such as these, lowering the costs of ensuring reliability. In addition, it would enable this effective method to be deployed across a wider customer base, which is critical as more renewables come online and grid operators are tasked with keeping up with the growing impacts of renewables.

Current and Projected Net Electricity Generating Capacity for renewables in the electricity Power sector, United States:

Forecasted Renewable Sources Table 1.3.3

Renewable Resource	Capacity in 2007	Projected Capacity in 2020
Conventional hydropower	76.72	77.12
Wind	16.9	33.20
Municipal waste	3.43	4.05
Geothermal	2.36	2.66
Wood and other biomass	2.18	4.24
Solar thermal	0.53	0.81
Solar photovoltaic	0.04	0.21
Offshore wind	0	0.20

Ireland currently forecasts that it will reach the renewable energy target of 16% addressed to it in Directive 2009/28/EC on a domestic basis.

The analysis underpinning these has been carried out by the sustainable energy authority, Sustainable Energy Ireland. The trajectory demonstrates Ireland meeting the overall 16% target for the share of energy from renewable sources in gross final consumption of energy by 2020 with 44% RES-E, 11%RES-T and 12% RES-H.

Ireland notes that this forecast is only based on preliminary modelling work and that the annual trajectories may differ significantly in Irelands final National Renewable Energy Action Plan to be submitted by 30 June 2010 under Directive 2009/28/EC. In particular, Sustainable Energy Ireland will be working on detailed modelling in the intervening period to identify the least cost trajectory towards achieving the overall target, which will be achieved from indigenous resources. This exercise, together with on-going policy developments, may influence the final National Renewable Energy Action Plan to be submitted.

1.4 Generation and Storage Equipment

Currently, electricity is produced in a few large facilities centres far away from consumptions points, which means that electric transformers are required to convert high voltage electricity in low voltage, and transport and distribution grids are necessary to transmit electricity to the end user. This electricity network structure and its operation presents some disadvantages that could be partly solved using local generation combined with storage systems.

By generating electricity in a lot of small generation systems near consumption points (local generation), distribution losses are minimized (distributing electricity from centralized systems involves almost 10% of losses as a consequence of transport); at the same time counting with a large number of generation points, the supply is guaranteed in case of default or power cut. Furthermore, this disseminated generation-network allows (if government policies in this scope have been developed) to exchange electricity among close local generators and consumers.

In addition, combining storage equipment with local generation makes possible to control better how electricity is going to be used. By adopting suitable strategies of consumption and storage it is possible to increase energy efficiency. Applying these strategies it will be decided for example, if electricity generated is used at this moment or, if there is no enough consumption demand (generation surplus), if electricity produced is stored to be used later or if it is injected into the distribution grid.

On the other hand, to have local generation and suitable systems to monitor and control electricity, obviously also counting with adequate protections, makes possible that a group of local generation systems work together in an isolated mode (separated from the distribution network) increasing supply reliability for the end user.

In order to perform these micro-grids it is necessary that government energy departments and utilities agree about what connection requirements (electricity parameters, protection devices…) must be carried out by local systems to obtain a balanced electricity system, also they must define new policies in order to allow local generator could participate in electricity market.

The following sub-sections detail:

- Generation sources: micro-generation, cogeneration
- Storage system: battery, building storage

1.5 Utility Company demand usage of renewables – generation & storage

Distributed generation (DG) is an approach that employs micro-small scale technologies to produce electricity close to the power end users. DG technologies often consist of modular (and sometimes renewable-energy) generators, and they offer a number of potential benefits. In many cases, distributed generators can provide lower-cost electricity and higher power reliability and security with fewer environmental consequences than traditional power generators.

In contrast to the use of a few large-scale generating stations located far from load centres, the approach used in the traditional electric power paradigm, DG systems employ numerous, but small plants and can provide power onsite reducing dependence on the distribution and transmission grids. The current model for electricity generation and distribution in Europe is dominated by centralized power plants. The power at these plants is typically fossil fuel based (coal, oil, and natural gas) or nuclear generated. Centralized power models require energy distribution from the centre to outlying consumers. Current substations can be anywhere, from 10s to 100s km away from the actual users of the power generated.

Through distributed generation many of large generation plant issues can be mitigated and benefits deriving from use of renewable sources and cogeneration may be fully exploited.

Consumer advocates, who favour DG, point out that distributed resources can improve the efficiency of providing electric power. They often highlight that transmission of electricity from a power plant to a typical user wastes up to 10% of the electricity as a consequence of aging transmission equipment, inconsistent enforcement of reliability guidelines, and growing congestion. At the same time, customers often suffer from poor power quality—variations in voltage or electrical flow—that results from a variety of factors, including voltage dips, interruptions, transients, and network disturbances from loads. Moreover, because customers' electricity bills include the cost of this vast transmission grid, the use of on-site power equipment can conceivably provide consumers with affordable power at a higher level of quality.

Cogeneration technologies permit the usage of thermal energy that would normally be wasted. They have therefore become usual in industries that use large quantities of heat, such as the iron and steel, chemical processing, refining, pulp and paper manufacturing, and food processing industries. Similar generation hardware can also deploy recycled heat to provide hot water for use in aquaculture, greenhouse heating, desalination of seawater, increased crop growth and frost protection, and air preheating. Beyond efficiency, DG technologies may provide benefits in the form of more reliable power for final users who require uninterrupted service.

1.6 Micro Generation

"Microgeneration" is used to denote electricity produced in a small scale (roughly less than 100kW) as an alternative to large centralized generation systems. This energy production system is very suitable to install in small buildings and households. The present section is going to focus "microgeneration" on renewable energies more specifically photovoltaic (solar) and wind systems. These energy sources have as a principal advantage that they are locally available; they do not need to be imported from other regions, reducing environmental impacts associated with transportation. Furthermore, to use renewable energy is one of the best options to reduce energetic dependency.

As a disadvantage it is necessary to be aware that sun and wind are random energy sources and they are not always available - that is why it is very important monitoring, controlling and managing them in order to apply suitable consumption strategies at all times to improve energy efficiency.

1.7 Photovoltaic energy

A photovoltaic (PV) generator system is mostly made up of solar panels and inverter(s). Solar panels are surfaces composed by photovoltaic cells faced to the sun (although they can also generate electricity in cloudy days). Cells (consist of one or two layers of a semi-conducting material) convert solar radiation into electricity (direct current), and the inverter is in charge of changing direct current (DC) into alternate current (AC) to be used in point consumptions. Electricity generated can be used at this time (self-consumption), sent to the grid or stored.

Solar panels are installed on any surface where there is sun radiation influence (roofs, terraces or on special structures…) and they are put into groups (arrays) to work together. There are several special types of solar panel (monocrystalline, policristalline, amorphous, etc.) available in the market to work in different meteorological and climate conditions in order to obtain the maximum efficiency according to the existing radiation. Also, it is possible to find many size and hardness grades (hard, flexible…) of solar panels able to be adapted to different surfaces in order to obtain a better architectural integration.

The inverter is a machine capable of modifying electricity generated in solar panels into electricity with the conditions required by the network. There are inverters with wide power ranges and it is possible to combine them (according to panel´s power) to work as a unique inverter if it is necessary. Inverters are located anywhere near the solar field whenever minimum protection conditions for the inverters will be guaranteed.

One of the most important advantages of photovoltaic systems is their flexibility and scalability to configure, depending on household requirements, or available space to install the panels. Furthermore, the owner of a PV system can enlarge or move it if his/her energy needs change.

The amount of electricity produced depends on facility performance (cell efficiency, inverter performance…) and irradiation grade (quantity of solar resource exists). In order to improve irradiation influence, panels could be better turn towards the sun: optimizing the tilt (using structures below the panel), or installing solar track systems.

Currently, the generation cost of PV electricity has become competitive, as a consequence of reducing manufacturing costs and increase in conversion efficiency. Thus, taking into account the solar resource is available everywhere, PV systems are one of the best options to generate distributed electricity in scalable form being respectful with environment and with reasonable cost.

Advanced control can help reduce operating costs and increase solar plant performance. The main control challenges are:

- Optimal robust control techniques able to maintain the operating temperature as close to optimum as possible despite disturbances such as changes in solar radiance level (caused by clouds), mirror reflectivity, and other operating conditions.
- Optimal and hybrid control algorithms that determine optimal operating points and modes and take into account the production commitments, expected solar radiation, state of energy storage, and electricity tariffs.
- Modes and methods for forecasting solar radiation using heterogeneous information (cameras, satellites, weather forecasts).

- Algorithms to estimate main process variables and parameters from heterogeneous and distributed measurements (oil temperature and solar radiation at different parts of the field, mirror reflectivity, thermal losses).
- Automatic mirror cleaning devices. The main factor degrading the optical performance of concentrating mirrors is accumulation of dirt on the mirror surface. Cleaning mirrors represents a considerable expense in manpower and water, usually a scarce resource where solar plants are located. Automatic devices need to be developed that minimize the use of water and degradation of the reflective surface.
- Heliostat self-calibration mechanisms. Heliostats need to be retuned periodically because of errors in the sun model, latitude and longitude of the site, heliostat position in the field, mechanical errors, optical errors, and the like. Heliostat recalibration may represent an important cost in manpower and time when done manually. Methods are needed for fast, automatic, online recalibration of heliostats.
- Fault detection and isolation in solar power plants. Algorithms are needed to detect and isolate faults and malfunctions in power plants, such as detection of hot spots, receivers with broken glass covers or vacuum losses, and heliostat faults.

Wind energy, One of the challenges of renewable power generation like wind and solar power is that it can be interrupted, and this variability affects the stability of the power produced .Power grids are facing a major transformation, driven by the need to integrate renewable energy, improve energy efficiency and allow consumers more control over their energy consumption.

Wind energy is converted into electricity by using wind turbines. These kinds of generator systems are made up for wind turbine plus an inverter. Wind turbine is mainly composed by: blades (where wind affects), nacelle (where rotor, gear box and generator are hosted), weather vane and tower, whole generator system is used to turn wind power into electricity (direct current). Later the inverter will transform DC current into AC. Electricity generated (like in PV systems) can be inserted in the network, consumed when it is produced, or stored.

There are plenty of wind turbine models, classified depending on:

- Axe type: vertical or horizontal
- Blade number: 2, 3 or multiple
- Power: wide range of power turbine available from kW to MW

The most important requirement to use wind energy systems is to have enough wind resource that accomplishes determined characteristics, as: frequency, variability, speed, … Before installing a wind generator it is necessary to have more information about this resource. This could be obtained through a measurement campaign (it is too expensive and it takes a long time at least one year), or analysing wind resource atlas and maps.

Wind is present everywhere in the world, thus taking into account the vast number of turbine models existent, it means that it is possible to install wind generators in many places choosing the suitable turbine in each location in such a way that it helps getting distributed generation.

Referring to constraints of this generation method, like in PV systems, the resource characteristics are very changeable. To have wind energy when it is needed is not always feasible.

Recently thanks to technological advances it was achieved that generation price of wind energy was similar to the cost of electricity generated with traditional sources which gives and additional and probably the definitive argument to use more and more this kind of facilities.

1.8 Co-generation

Cogeneration facilities are systems that produce both electricity and thermal energy using as combustible mostly natural gas; they can also work with renewable energy sources and biomass or other traditional combustibles.

It is the technology that better provides high efficiency in electricity generation. It is based on using in the own production centre (or close) the heat that it is produce while a combustible is been converting into electricity. While large thermal facilities are only looking for electricity generation and they disperse generated heat to the environment, cogeneration facilities obtain an increase of global efficiency given that they exploit this heat. Cogeneration, as well as being an efficient electricity production solution itself, avoids losses in the electric grid, considering that cogeneration, like distributed generation, focuses in producing electricity and heat near consumption points.

There is a concept widening about cogeneration that allows obtaining electrical and heat energy and also cooling from waste heat. It is named tri-generation, and it allows cooling from heat sources using absorption systems. As a result, an increase of efficiency is obtained in most of climates, considering that heat is necessary only a few months per year, as during the hot seasons air-conditioning can be used.

Cogeneration is mainly for industrial applications, where heat produced can be used for heating, air-conditioning (through absorption systems), heating water (e.g. universities, hospitals), although it is difficult to fit in households.

Common elements in all cogeneration plants are:

- Primary energy source: natural gas, fuel, renewable energies.
- Conversion of thermal or chemical energy into mechanical energy.
- Heat exploitation system: heat recovering boilers, absorption units, etc.

Plant´s efficiency can be measured through some coefficients, such as energy use factor (quotient from generated electric energy plus useful heat, divided by supply heat) or heat/electricity ratio (useful heat divided by generated electric power). The first coefficient is the most important considering it gives us an idea about the facility global performance.

Concerning the control of cogeneration systems, it is important to note that the cogeneration process is distributed between electrical/mechanical production and heat. As the needs for these energies can change in different ways it is frequent that a surplus of one of them occurs. Therefore, it is important to count with suitable control and monitoring systems.

Currently, the cogeneration potential in Europe is approximately 150 GW, thus it can play a key role in European energetic strategies. This mature technology for the generation of electricity and heat contributes directly to achieve the three main objectives of European policies: climate change, supply reliability and competitiveness.

1.9 Battery

It is called electrical battery or storage battery, the device that stores electric energy through electrochemical processes in order to return it later almost in full (although this cycle can only be done a limited number of times). Battery is a secondary electric generator; it means a generator that needs previously supplied electricity (load process).

The most important battery technical characteristics are the voltage (it is the first parameter to consider in a battery selection given that it indicates if battery is suitable for achieving the purpose), current (second parameter to consider taking into account storage capacity level), charge and discharge constant (C is a constant, given by the manufacturer, used to show how many amperes should been charged o discharged for avoiding battery damages).

One of the main problems of electric supply is the difficulty (and high cost) to store energy during low demand periods in order to use it after in peak periods. This fact is particularly relevant form the point of view of renewable energies, if the aim is that they will be an option in front of traditional combustibles. Of course networks are capable to diversify energy sources and moving electricity to other places in the grid in order to face demand peaks, but it would be easier and more efficient if electricity could be stored locally in a large scale. Besides, taking into account that more and more local generators are being used and that they will want to exchange electricity, it is necessary to guarantee reliability and quality power through an intelligent management, therefore energy storage in battery plays an essential role.

a) Always available energy
Batteries allow having energy anytime regardless of when it is generated. This characteristic is really important for renewable energies given that they are strongly conditioned on environmental factors like sun or wind. Batteries can be used for balancing differences between demand and offer from offer/demand energy point of view and considering the associated cost of energy provided.

b) Power adjustments
Sometimes sudden situations occur that produce important fluctuations in the power needs of electric systems; also in these moments batteries can play a very important role in order to adjust grid operation.

c) Stability of the grid
Energy stored in batteries is supplied with suitable voltage and power values. One of the main distribution problems is to be capable to offer accurate and quality electricity values to the end users. Batteries guarantee the supply with these requirements.

Disadvantages
Employing batteries has several advantages, as presented above, but also has some important advantages that should be considered:

a) Memory effect: it is an effect produced in batteries as a consequence of charge and discharge processes. With each charge, voltage is limited (caused by long time, high temperature or high current), reducing capacity for storing energy as a result of crystals generation inside the battery.

b) Accumulators like contaminants: the majority of batteries contains heavy metals and chemical compounds, most of them harmful for environmental. That is why it is mandatory to take them to recycling centres.

Finally, it is important to note the importance of batteries applied to electric vehicles which can provide one more advantage: the possibility to flatten the demand curve charging EV during valley periods of electricity demand.

1.10 Building storage

Currently, with the high penetration of renewable energy sources, it is urgent to consider how surplus of electricity generated is going to be stored in order to be used when renewable sources are not available. Particularly, it is important to focus on building storage to get more efficiency energy, where buildings are transformed into energy suppliers (prosumers) participating in an electric embedded bidirectional system. It is essential integrating, managing and controlling a large number of households like a unique energy plant.

Traditionally, more common storage systems have been batteries but they have a lot of constraints can be expensive and have a limited number of charge/discharge cycles and when they arrive to the end of their useful life it is very complicated to treat the chemical waste. That is why other innovative systems should be considered.

- CAES systems: this storage system is based on compressing air through solar and wind generators, after stored it in containers in order to propel turbines later, thus generating electricity. As big as building is, CAES system is cheaper.
- Flywheel and batteries: system used to apply an active management of electricity demand through electric storage. Flywheels allow to provide grid quality and regulation to renewable energies.
- Hydrogen piles: using surplus of solar energy is possible to generate hydrogen to be stored in tanks in order to be used later like combustible piles for example.

1.11. Define various models of operation

1.11.1 Remote access and control of application

Encourage platform allows the users to remotely control and monitor components within the building or home through the communication concentrators. Commercial and residential users within the ENCOURAGE platform will be will be provided with a group of services allowing the user to create an initial setup configuration of the network with the devices listed with the capabilities of removing or adding a selected device or change the selected devices properties. Devices once connected to the network will allow the user remote access to remotely turn on/off devices and alter settings. Pre-defined actions such as adjust set points , delay start and switch off devices will be triggered by the user who can configure specific rules and take into context dynamic changes like weather conditions and real-time prices.

1.11.2 Energy Monitoring, visualization and reporting

Users of the ENCOURAGE platform will be provided with a range of monitoring, reporting and visualisation services. Information will be presented at different levels of detail, ranging from an overall global view scaling down to an individual device. The user will have the option to select different time intervals from minutes-hours to day-months. Reports on energy consumption, detected problems or suggested steps will be generated at regular intervals (e.g. daily, weekly, monthly) or on demand. The platform will offer the user a comparison of the consumption of energy been used against the expected usage, this will be based on historical data. Monitoring of specific individual devices will allow the user to see if an individual device is operating at full performance.

1.11.3 Load Management

Real time prices and demand response events have a huge effect on the electricity market and the end user must have the ability to deal with these dynamic changes, therefore a constant control of the electrical load is needed. Load management in the ENCOURAGE platform will greatly reduce energy consumption in the building or home whilst taking into account user preferences, external conditions such as weather. The user will have the ability to add specific applications or a group of applications to the load management and then will be managed by the platform. This platform will ensure that users cost are kept to a minimum. The user at all times will have the authority to override the decisions made by the automated load management system

1.11.4 Micro-grid energy management

Services provided by the ENCOURAGE platform will be tailored to the needs of the local communities and neighbourhoods, which might be running local grids with potentially multiple generation, consuming and storage elements connected to that grid. There needs to be the necessary balance between energy generation and energy consumption .To ensure this balance monitoring is necessary on renewable resources as as generation source are intermittent.

1.11.5 Distribution system operation

The ENCOURAGE platform can offer real-time information about generation and consumption of electricity in a given locality and can show how the real-time information deviates away from the expected behaviour. With the historic data available the platform will be able to provide forecasts depending on the user needs ranging from 2-3 hours or a number of days ahead.

	Remote access and control of application	Energy Monitoring, Visualization and reporting	Load Management	Microgrid energy management	Distribution system operation
Residential Consumers	X	X	X		
Residential Prosumers	X	X	X	X	
Commercial building Prosumers	X	X	X	X	
Local energy producers	X	X		X	
Aggregators		X		X	
Distributed system operators		X	X		X

1.12 Protocol required for each technology

All the technology discussed in this chapter utilise various different protocol to manage their respective on-board intelligence, this section will examine some of the most popular industry used protocols.

1.12.1 SNMP

Simple Network Management Protocol (SNMP) is a widely used protocol for monitoring the health and welfare of network equipment (eg. routers), computer equipment and even devices like UPSs. Net-SNMP is a suite of applications used to implement SNMP v1, SNMP v2c and SNMP v3 using both IPv4 and IPv6. The suite includes:

- Command-line applications to:

  - retrieve information from an SNMP-capable device, either using single requests (snmpget, snmpgetnext), or multiple requests (snmpwalk, snmptable, snmpdelta).
  - manipulate configuration information on an SNMP-capable device (snmpset).
  - retrieve a fixed collection of information from an SNMP-capable device (snmpdf, snmpnetstat, snmpstatus).
  - convert between numerical and textual forms of MIB OIDs, and display MIB content and structure (snmptranslate).

- A graphical MIB browser (tkmib), using Tk/perl.
- A daemon application for receiving SNMP notifications (snmptrapd). Selected notifications can be logged (to syslog, the NT Event Log, or a plain text file), forwarded to another SNMP management system, or passed to an external application.
- An extensible agent for responding to SNMP queries for management information (snmpd). This includes built-in support for a wide range of MIB information modules, and can be extended using dynamically loaded modules, external scripts and commands, and both the SNMP multiplexing (SMUX) and Agent Extensibility (AgentX) protocols.
- A library for developing new SNMP applications, with both C and perl APIs

1.12.2 RS232

RS-232 is simple, universal, well understood and supported but it has some serious shortcomings as a data interface. The standards to 256kbps or less and line lengths of 15M (50 ft) or less but today we see high speed ports on our home PC running very high speeds and with high quality cable maxim distance has increased greatly. The rule of thumb for the length a data cable depends on speed of the data, quality of the cable.Electronic data communications between elements will generally fall into two broad categories: single-ended and differential. RS232 (single-ended) was introduced in 1962, and despite rumors for its early demise, has remained widely used through the industry.

Independent channels are established for two-way (full-duplex) communications. The RS232 signals are represented by voltage levels with respect to a system common (power / logic ground). The "idle" state (MARK) has the signal level negative with respect to common, and the "active" state (SPACE) has the signal level positive with respect to common. RS232 has numerous handshaking lines (primarily used with modems), and also specifies a communications protocol.The RS-232 interface presupposes a common ground between the DTE and DCE. This is a reasonable assumption when a short cable connects the DTE to the DCE, but with longer lines and connections between devices that may be on different electrical busses with different grounds, this may not be true.

RS232 data is bi-polar.... +3 TO +12 volts indicates an "ON or 0-state (SPACE) condition" while A -3 to -12 volts indicates an "OFF" 1-state (MARK) condition.... Modern computer equipment ignores the negative level and accepts a zero voltage level as the "OFF" state. In fact, the "ON" state may be achieved with lesser positive potential. This means circuits powered by 5 VDC are capable of driving RS232 circuits directly, however, the overall range that the RS232 signal may be transmitted/received may be dramatically reduced.The output signal level usually swings between +12V and -12V. The "dead area" between +3v and -3v is designed to absorb line noise. In the various RS-232-like definitions this dead area may vary. For instance, the definition for V.10 has a dead area from +0.3v to -0.3v. Many receivers designed for RS-232 are sensitive to differentials of 1v or less.

This can cause problems when using pin powered widgets - line drivers, converters, modems etc. These types of units need enough voltage & current to power them self's up. Typical URART (the RS-232 I/O chip) allows up to 50ma per output pin - so if the device needs 70ma to run we would need to use at least 2 pins for power. Some devices are very efficient and only require one pin (sometimes the Transmit or DTR pin) to be high - in the "SPACE" state while idle.

An RS-232 port can supply only limited power to another device. The number of output lines, the type of interface driver IC, and the state of the output lines are important considerations. The types of driver ICs used in serial ports can be divided into three general categories: Drivers which require plus (+) and minus (-) voltage power supplies such as the 1488 series of interface integrated circuits. (Most desktop and tower PCs use this type of driver.)Low power drivers which require one +5 volt power supply. This type of driver has an internal charge pump for voltage conversion. (Many industrial microprocessor controls use this type of driver.)Low voltage (3.3 v) and low power drivers which meet the EIA-562 Standard. (Used on notebooks and laptops.)Data is transmitted and received on pins 2 and 3 respectively. Data Set Ready (DSR) is an indication from the Data Set (i.e., the modem or DSU/CSU) that it is on. Similarly, DTR indicates to the Data Set that the DTE is on. Data Carrier Detect (DCD) indicates that a good carrier is being received from the remote modem.

Pins 4 RTS (Request To Send - from the transmitting computer) and 5 CTS (Clear To Send - from the Data set) are used to control. In most Asynchronous situations, RTS and CTS are constantly on throughout the communication session. However where the DTE is connected to a multipoint line, RTS is used to turn carrier on the modem on and off. On a multipoint line, it's imperative that only one station is transmitting at a time (because they share the return phone pair). When a station wants to transmit, it raises RTS. The modem turns on carrier, typically waits a few milliseconds for carrier to stabilize, and then raises CTS. The DTE transmits when it sees CTS up. When the station has finished its transmission, it drops RTS and the modem drops CTS and carrier together. Clock signals (pins 15, 17, & 24) are only used for synchronous communications. The modem or DSU extracts the clock from the data stream and provides a steady clock signal to the DTE. Note that to transmit and receive clock signals doesn't have to be the same, or even at the same baud rate. Note: Transmit and receive leads (2 or 3) can be reversed depending on the use of the equipment - DCE Data Communications Equipment or a DTE Data Terminal Equipment.

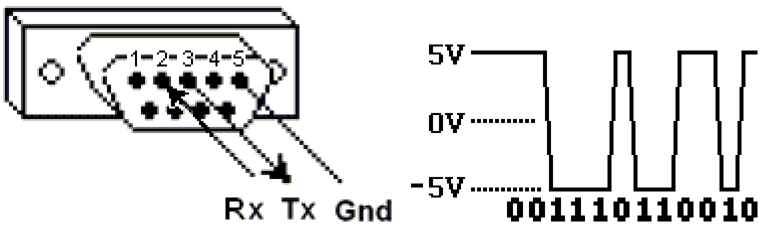
1.12.3 RS485

RS-485, is a standard defining the electrical characteristics of drivers and receivers for use in balanced digital multipoint systems. The standard is published by the Telecommunications Industry Association/Electronic Industries Alliance (TIA/EIA). Digital communications networks implementing the EIA-485 standard can be used effectively over long distances and in electrically noisy environments. Multiple receivers may be connected to such a network in a linear, multi-drop configuration. These characteristics make such networks useful in industrial environments and similar applications.

1.12.4 MODBUS

Modbus is a serial communication protocol developed by Modicon published by Modicon® in 1979 for use with its programmable logic controllers (PLCs). In simple terms, it is a method used for transmitting information over serial lines between electronic devices. The device requesting the information is called the Modbus Master and the devices supplying information are Modbus Slaves. In a standard Modbus network, there is one Master and up to 247 Slaves, each with a unique Slave Address from 1 to 247. The Master can also write information to the Slaves.

Modbus is an open protocol, meaning that it's free for manufacturers to build into their equipment without having to pay royalties. It has become a standard communications protocol in industry, and is now the most commonly available means of connecting industrial electronic devices. It is used widely by many manufacturers throughout many industries. Modbus is typically used to transmit signals from instrumentation and control devices back to a main controller or data gathering system, for example a system that measures temperature and humidity and communicates the results to a computer. Modbus is often used to connect a supervisory computer with a remote terminal unit (RTU) in supervisory control and data acquisition (SCADA) systems. Versions of the Modbus protocol exist for serial lines (Modbus RTU and Modbus ASCII) and for Ethernet (Modbus TCP).Modbus is transmitted over serial lines between devices. The simplest setup would be a single serial cable connecting the serial ports on two devices, a Master and a Slave.



The data is sent as series of ones and zeroes called bits. Each bit is sent as a voltage. Zeroes are sent as positive voltages and a ones as negative. The bits are sent very quickly. A typical transmission speed is 9600 baud (bits per second).

The official Modbus specification can be found at www.modbus-ida.org.

1.12.5 zWAVE

Z-Wave is a next-generation wireless ecosystem that lets all your home electronics talk to each other, and to you, via remote control. It uses simple, reliable, low-power radio waves that easily travel through walls, floors and cabinets. Z-Wave control can be added to almost any electronic device in your house, even devices that you wouldn't ordinarily think of as "intelligent," such as appliances, window shades, thermostats and home lighting.

Z-Wave unifies all your home electronics into an integrated wireless network, with no complicated programming and no new cables to run. Any Z-Wave enabled device can be effortlessly added to this network, and many non-Z-Wave devices can be made compatible by simply plugging them into a Z-Wave accessory module. In seconds, your device gets joined to the network and can communicate wirelessly with other Z-Wave modules and controllers.

And Z-Wave lets you control these devices in ways that give you complete command even when you're not at home yourself. You can control your Z-Wave household remotely from a PC and the Internet from anywhere in the world...even through your cell phone!

- Z-Wave Is Simple – Z-Wave control is easily added to almost any device in minutes. Simply plug the device you want to control into a Z-Wave module, and "join" it to your Z-Wave network! You can add Z-Wave to a device, a room, a floor or the entire home, according to your needs and desires.

- Z-Wave Is Affordable – Unlike costly whole-home control systems that need special wiring and professional installation, Z-Wave is accessible and easy for the do-it-yourself.

- Z-Wave Is Powerful – Z-Wave's intelligent mesh networking 'understands" the present status of any enabled device, and gives you confirmation that your devices have received the automatic or manual control commands you want.

- Z-Wave Is Versatile – Z-Wave can be added to almost anything in your home that uses electricity, and gives you the power to control or monitor them from your home or away from home.

- Z-Wave Is Intelligent – Z-Wave enabled devices can work together as a team. Have your garage door turn on your house lights when you come home. Have your door locks notify you when your children arrive home from school. Turn your downstairs lights off from upstairs. Create your own intelligent control "scenes" with Z-Wave!

Z-Wave delivers on all the promises of the wired home, and opens up exciting new possibilities for the home of the future. And that future is here now, because hundreds of Z-Wave enabled products are already widely available, from some of the best-known brands that you already know and trust. Take a few moments to browse through this site and better acquaint yourself with Z-Wave. Get to know how Z-Wave makes your home -- and your life -- safer, more secure, more economical, more convenient and more enjoyable!

1.12.6 ZIGBEE

ZigBee Smart Energy is the world's leading standard for interoperable products that monitor, control, inform and automate the delivery and use of energy and water. It helps create greener homes by giving consumers the information and automation needed to easily reduce their consumption and save money, too.

ZigBee Smart Energy version 1.1, the newest version for product development, adds several important features including dynamic pricing enhancements, tunnelling of other protocols, prepayment features, over-the-air updates and guaranteed backwards compatibility with certified ZigBee Smart Energy products version 1.0. You can also watch our webinar from April, 2012 to learn even more about how companies are using it to deliver energy management to consumers today.

This standard supports the diverse needs of a global ecosystem of utilities, product manufacturers and government groups as they plan to meet future energy and water needs.

All ZigBee Smart Energy products are ZigBee Certified to perform regardless of manufacturer, allowing utilities and consumers to purchase with confidence. Every product needed to implement a robust ZigBee Smart Energy home area network (HAN) is available. These products make it easy for utilities and governments to deploy smart grid solutions that are secure, easy to install and consumer-friendly.

Some of the world's leading utilities, energy service providers, product manufacturers and technology companies are supporting the development of ZigBee Smart Energy. Several other standards groups are also involved with extending the reach of ZigBee Smart Energy to more homes around the world.

2. Sub Metering & Control Technologies

2.1 Introduction

Distributed generation (DG) encompasses a wide range of prime mover technologies, such as internal combustion engines, gas turbines, micro-turbines, photovoltaic, fuel cells and wind-power. Penetration of distributed generation has not yet reached significant levels. However that situation is changing rapidly and requires attention to issues related to high penetration of distributed generation within the distribution system. ENCOURAGE platform realizes the emerging potential of DG taking an approach which views generation and associated loads as a subsystem or a micro-grid. ENCOURAGE concept is an advanced approach for enabling integration of, in principle, an unlimited quantity of distributed energy resources into the electricity grid. The micro-grid concept is driven by a fundamental principle: A systems perspective is necessary for customers, utilities, and society to capture the full benefits of integrating distributed energy resources into an energy system.

2.2 Metering Requirements

The ENCOURAGE platform will be designed in such a way as to enable energy generation monitoring for the purpose of determining overall system performance. Typically this will require monitoring of all the inputs and outputs to the Renewable Energy System Equipment (RESE), including, but not limited to, provisions for the following:

- Electrical meters for monitoring electrical requirements of all RESE, including heat pumps, pumps, motorized valves, etc.
- Sensors and flow meters should be capable of logging data for use in performance monitoring and reporting.
- Heat pump system monitoring controls shall include inlet and outlet temperature sensors and a flow meter (or BTU meter) on both the source side (ground or air loop) and load side (building loop) for the purpose of monitoring system performance and building energy demand
- Domestic Hot Water systems shall include flow meters for the purpose of estimating hot water energy demand.
- Gas-fired systems shall include inlet and outlet temperature sensors and a flow meter (or BTU meter) on the building loop, and totalizing gas meters to measure fuel usage.

Alternative means of system monitoring may be included if necessary.

2.3 Information Requirements

Renewable energy system monitoring must enable collection and calculation of the following:

- Total monthly electricity consumption of RES
- Total monthly natural gas consumption of RES
- Boiler efficiencies
- Coefficients of performance of heat pumps in cooling and heating mode
- Total monthly and peak monthly heating demand
- Total monthly and peak monthly cooling demand
- Total monthly and peak monthly domestic hot water demand
- Heat pump source side entering fluid temperatures and seasonal changes in the entering fluid temperatures from the geo-exchange field (if applicable)
- Percentage of heating and cooling energy demands being met by renewable sourced energy.

Specific requirements may additionally include the design and demonstration of:

- Advanced metering and information technologies that can measure and communicate the time-varying value of interval energy and ancillary service contribution.
- Control and optimization technologies for end-use equipment that can facilitate flexible response to time-varying prices and security management protocols
- Improved power electronic devices that have lower life-cycle costs and can withstand higher voltages, currents, switching frequencies and power densities.
- Compact, high capacity and cost-effective reversible energy storage technologies.

2.4 Define process for monitoring of local generation

2.4.1 Introduction

The rationale for requiring performance monitoring and reporting of renewable energy systems is to:

- Assess short- and long-term system performance and provide opportunities for optimization of system operation for the purpose of improving on-going system performance and efficiency.
- Confirm actual building energy demands for domestic hot water heating, and space and ventilation air heating and cooling, and to improve understanding of the performance, reliability, and long-term sustainability of renewable-sourced systems

2.4.2 Definitions

Performance Monitoring means the collection, synthesis, and interpretation of renewable energy system performance metrics including energy inputs, energy demands, coefficients of performance, and trends in long-term system performance. Specific performance monitoring requirements are outlined below.

Renewable Energy System (RES) means a thermal energy generating, distribution, and delivery system that incorporates low-carbon energy sources (such as sewage heat recovery, geo-exchange, surface water exchange, waste heat recovery, air source heat pumps, solar thermal, biomass, etc.) for space and domestic hot water heating, and in some cases cooling, for the development, and that may include conventional heating and cooling sources (such as boilers, chillers, cooling towers, etc.) to satisfy peaking and backup thermal energy requirements.

Renewable Energy System Equipment (RESE) means all the mechanical and electrical equipment used to produce and distribute water for heating, cooling and domestic hot water as part of the Renewable Energy System. This equipment will likely consist of heat pumps, chillers, boilers, cooling towers, distribution or circulation pumps, heat exchangers, air handling units, etc. Typically most of this equipment would be located in a common HVAC mechanical room.

Renewable Energy System Monitoring

Tracking RES requires an energy monitor to have a dedicated channel for that purpose. This channel must be in addition to those channels used to track total load or specific appliance loads. When alternative power is tracked against total load the net result is the number of kilowatt-hours. Each channel of the energy monitor will require a separate set of current transformers (CT). These CTs measure the current generated by the renewable energy source. They must be located on the conductors coming from this alternate energy source prior to entering a transfer switch or circuit breaker in the distribution panel or else measurements will not be accurate.

Since wind speeds change, clouds pass in front of the sun and stream levels fluctuate alternate power generated by renewable energy sources is not usable in standard electrical distribution networks. It must be rectified (AC/DC) and/or inverted (DC/AC) to become usable. This power must have the proper voltage and frequency to compatible with standard household power.

Given these considerations, the best location to measure the true output of renewable energy sources is on the load side of the rectifier and/or inverter before power enters the main circuit breaker panel. Alternative power can now be measured at standard voltage and frequency and includes any efficiency losses caused by the rectifier and/or inverter.

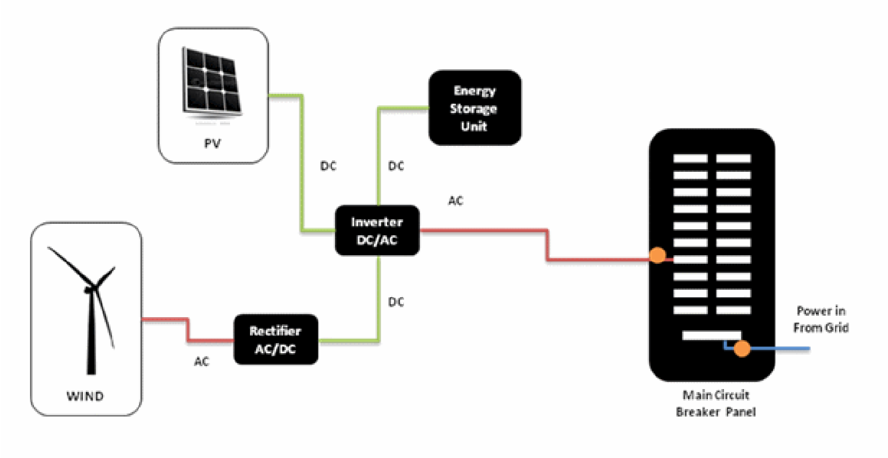


Figure 1. RES Monitoring

The above diagram (Figure 1) provides a generic description of where the CTs should be located when wiring an energy monitor to track alternate energy.

Solar power panels capture sunlight and convert it into direct current or DC. Sun angle, time of day and level of overcast all effect the amount of power that can be generated. Direct current (DC) must be converted to alternating current (AC) using an inverter in order for it to work with standard household power. Inverter inefficiencies can be high robbing as much as 20 to 30 percent of the total energy generated by the solar array.

Solar thermal uses the sun's energy to heat water, or glycol, if a heat exchanger is used. This heated water supplements existing hot water systems. Measuring the amount of electrical energy saved by solar thermal should be done deductively. Setting up a baseline by logging the amount of energy required without solar thermal, measuring again with solar thermal operating and net out the difference. Load profiling or sub-metering the hot water heater is a good way to do this. Logging outside air temperature and match weather conditions before and after for a more accurate comparison.

Since the output power of a solar array depends on environmental factors such as solar radiation and temperature, an understanding of how system performance correlates with environmental data is needed. Historical data can provide information on power output trends.

Sensing and instrumentation components of a typical solar monitoring system are shown below. Solar irradiance sensors enable the monitoring system to measure the amount of sunlight reaching the panels. Monitoring the temperature of the solar array is important since power generation performance also depends on temperature. By comparing the expected power output of the system based to the actually power output, performance metrics such as array utilization are calculated. An unexpected drop in array utilization typically indicates a problem that should be evaluated by maintenance crews. Inverter monitoring is another key part of a solar monitoring system to monitor the efficiency, performance and reliability of the solar inverters.

Measurement	Signal
Solar Panel	DC Current, Voltage
Battery	DC Current, Voltage
Load Power Consumption	DC Current, Voltage
Grid Power	AC Current, Voltage

Table x. Electrical power measurements

Measurement	Typ. Transducer	Typ. Signal
Solar Irradiance	Pyranometer	Analog Voltage
Wind Speed	Anemometer	Pulse train
Wind Direction	Anemometer	Analog Resistance (pot wiper)
Ambient Temperature	Thermocouple	Analog Voltage
Panel Temperature	Thermocouple	Analog Voltage

Table x. Solar environmental monitoring

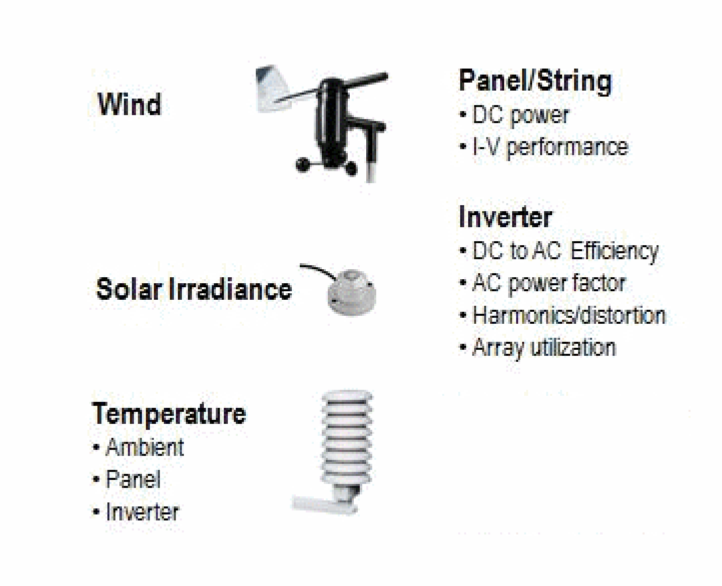


Figure 2. Solar monitoring sensors

Because of wind energy flucations the use of S**ensing and monitoring** of operational parameters plays a key role due to variability in wind speed and direction, the need to detect abnormal behavior before energy production and safety are compromised and the enormous costs attributed to maintenance. **Wireless sensor networks** market solutions are ideally suited for **condition monitoring** of critical turbine components such as bearings, gearbox and generator.

Output power of a Wind RES depends on environmental factors such as wind speed and wind direction, again an understanding of how system performance correlates with environmental data is needed, air temperature, barometric pressure and relative humidity.

2.5 Control logic for micro-grid with multiple generation and storage devices

2.5.1 Introduction

As previously presented, distributed generation is becoming an increasingly attractive approach to reduce greenhouse gas emissions, to improve power system efficiency and reliability, and to relieve stress on power transmission and distribution infrastructure. Distributed generation encompasses a wide range of prime mover technologies, such as internal combustion engines, gas turbines, micro-turbines, photovoltaic, fuel cells and wind power. A better way to realize the emerging potential of distributed generation is to take a system approach which views generation and associated loads as a micro-grid.

Micro-grid is a concept of defining the operation of distributed generation, in which different micro-sources operate as s single controllable system that provides power and heat to a cluster of loads in the local area.

The micro-grid is a promising concept in several fronts because it:

- minimizes emissions and system losses.
- provides systematic approaches to utilize diverse and distributed energy sources for distributed generation
- provides uninterruptible power supply functions

Despite many advantages of micro-grids there remain many technical challenges and difficulties in this new power industry area. One of them is the design, acceptance, and availability of low-cost technologies for installing and using micro-grids. The increased deployment of power electronic devices in alternative energy sources within micro-grids requires effective monitoring and control systems for safe and stable operation while achieving optimal utilization of different energy sources. Micro-generation suffers from lack of experience, regulations and norms. Because of specific characteristics of micro-grids, such as high implication of control components, large number of micro-sources with power electronic interfaces remains many difficulties in controlling of micro-grids. Realization of complicated controlling processes requires specific communication infrastructure and protocols. During the process of organization many questions concerning the protection and safety aspects emerge. Also, it is required to organize free access to the network and efficient allocation of network costs.

2.5.2 Background

A micro-grid is described as a small power system with three primary components: distributed generators with optional storage capacity, autonomous load centres, and system capability to operate interconnected with or islanded from the larger utility electrical grid.

2.5.3 Micro-grids include several basic components for operation

Distributed generation units are small sources of energy located at or near the point of use. There are two basic classes of micro-sources; DC source (fuel cells, photovoltaic cells, etc.), high frequency AC source (micro-turbines, wind generators), which needs to be rectified. An AC micro-grid can be connected to low voltage or medium voltage power distribution networks; ENCOURAGE focus in the first.

Storage technologies are used in micro-grid applications where the generation and loads of the micro-grid cannot be exactly matched. These technologies provide a bridge in meeting the power and energy requirements of the micro-grid. Storage enhances micro-grid systems overall performance in three ways:

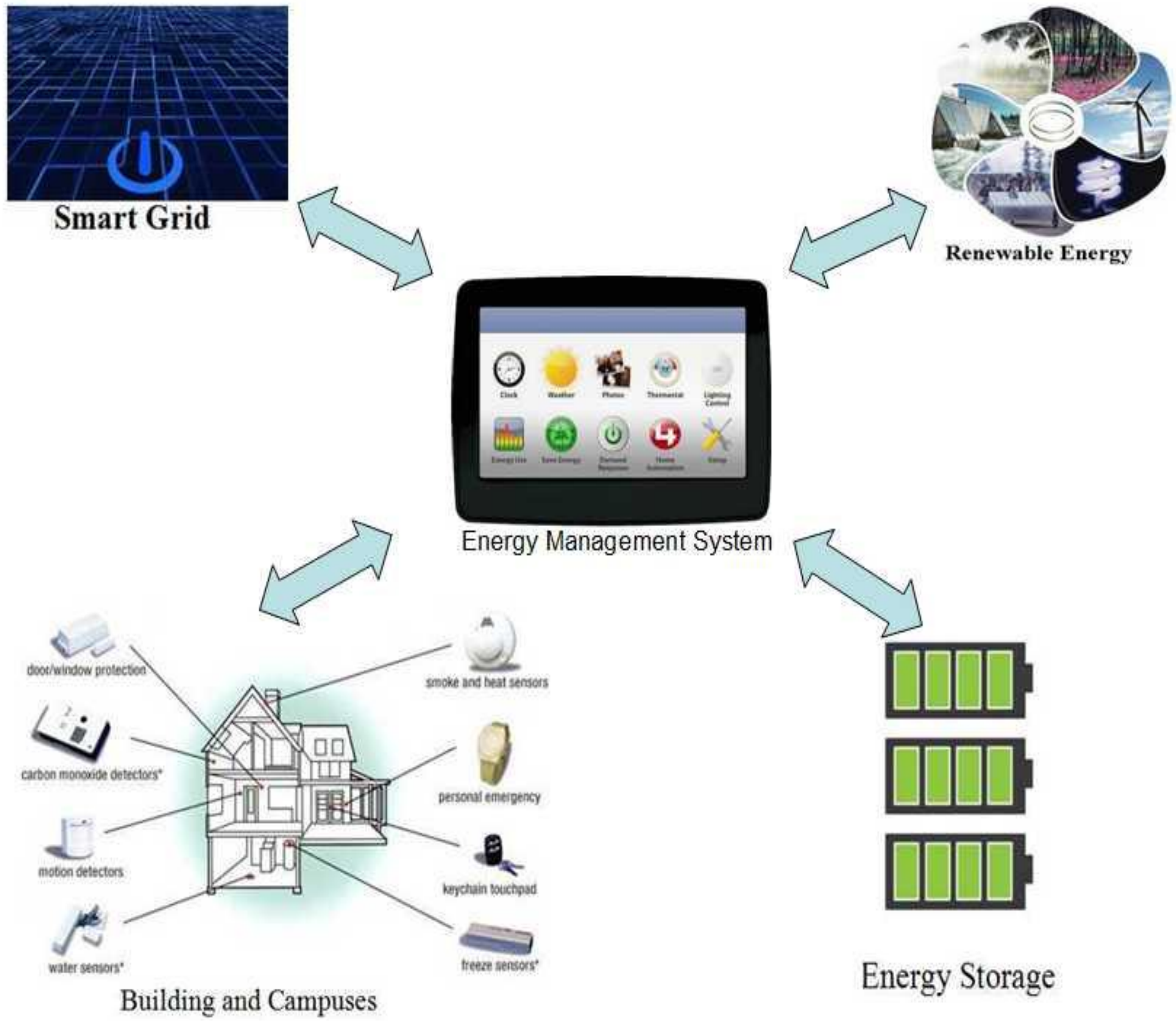
- stabilizes and permits distributed generation units to run at a constant and stable output, despite load fluctuations.
- provides the ride through capability when there are dynamic variations of primary energy such as those of sun, wind, and hydropower sources)
- permits distributed generation to seamlessly operate as a dispatchable unit.

There are several forms of energy storage, such as the batteries and supercapacitors.
The control system of a micro-grid must be designed to safely operate the system in grid-parallel and stand-alone modes. This system may be based on a central controller or imbedded as autonomous parts of each distributed generator. When the utility is disconnected, the control system must control the local voltage and frequency, provide (or absorb) the instantaneous real power difference between generation and loads, provide the difference between generated reactive power and the actual reactive power consumed by the load, and protect the internal micro-grid.

3. Communication and Control Technologies

3.1 Introduction

Communication and Control Technologies are vital aspects to the Encourage platform. In the figure below we see that communication is made bi-directional and control technologies either legacy or new must be able to support communication between all areas of the ENCOURAGE platform. The management system must communicate with the smart grid, renewable energy resources, building, campuses and UPS's and using the defined set of rules/algorithms determine which line of communication and events to be carried out. For this communication to be carried out we must define the control technologies used.



3.2 Integrating algorithms and decision capabilities for energy generation into local control devices.

There are two main approaches for home energy-demand management. The first one goes for a direct control of the domestic loads by an external entity (e.g. the electrical utility, a network manager, or the local transformation centre). This approach is based on the industrial energy-management systems, where the electrical utility may disconnect a series of loads when a variation in the generation/demand pair is observed. These systems are the most beneficial ones for the network manager, as they allow a direct control over the energy demand, but have an impact on the user comfort, as external entities enter his/her home. This is why the second energy-management approach goes for an indirect control, where the loads are controlled entirely inside the home itself.

We can define energy-demand management as a problem of order and optimization. In order to deal with this problem the control algorithm needs to know the future behaviour of the loads (i.e. the forecast of their power consumption). This forecast may be obtained through measurement, statistics, learning, etc. The loads can be divided into three categories:

1. Active loads: we know their consumption forecast and we can act on their behaviour.
2. Informative loads: we know their consumption forecast but we cannot act on their behaviour.
3. Non-informative loads: we do not know about their consumption forecast and we cannot act on their behaviour either.

The following solutions have been proposed in order to act on the non-active loads:

- To change their control hardware by another one, which allows energy management?
- To follow their behaviour closely by sensors.
- To control their consumption directly with switches.

Even in the cases where it is not possible to act on the loads, consumption needs to be taken into account, so it is advisable to create a virtual load in the management system in order to reflect their behaviour.

3.2.1 Direct Control

After a big study about home-level electrical-energy consumption in UK, results obtain peak-consumption reductions up to 60% by using control algorithms in the cooking and washing devices. They evaluate the removal of consumption peaks by integral control (avoiding simultaneous peaks) and thermal storage. On the other hand, the analysis of home-level energy consumption indicates that:

1. The energy consumption is not constant. In most cases, consumption peaks are much higher than the average value.
2. The consumption value depends on the number of inhabitants and their incomes.
3. Consumption patterns adjust to two types, depending on the activity periods:
   a. People most of the time at home and needing heating system for most of the day.
   b. People most of the time out of home and needing heating system only in the morning and in the evening.

Cooking, cloth-washing and dishwashing activities have been identified as responsible for consumption peaks, as they make use of high-power electrical heaters for a fast operation. Simultaneity of these activities may generate peaks over 10 kW, so controls have been implemented in order to avoid this.

Electrical kitchens are the ones which generate the biggest peaks of energy-demand. They are normally controlled with on/off cycles; therefore, a control algorithm has been implemented in which minimizes these peaks, avoiding to a certain extent the overlap of the on-cycles of the different cooking plates.

On the other hand, washing machines have a 10-30 minute heating period at the beginning of their 60-90 minute cycle, and dishwashers have two heating periods of 10-15 minutes each. Control algorithms have been implemented which reduce the peak consumption of these devices, reducing the power of the heaters while increasing the duration of the washing cycles.

Other home devices (television, refrigerator, DVD player, etc) individually have low power consumption (10-200 W) and do not have a significant margin for improvement. The same thing happens with lights: even if it can be controlled in a more efficient way (e.g. by the use of presence sensors), peak reduction values are too small. Other devices, such as toasters, microwave ovens, dryers and hoovers have been defined as non-switchable, proposing a warning system which recommends postponing their use.

Another option is the use of a centralized load-management control system in order to smoothen the consumption profile. Depending on the consumption value, they apply the controls mentioned before and also delay/switching strategies. Load shedding (e.g. switching off alternatively a heater for a short period of time during periods of high consumption) is a suitable way of avoiding peaks for several devices (ovens, cooking plates, washing machines and dishwashers). This option, however, should have low priority in the control hierarchy, as it might go against the user preferences. They suggest that the user should be able to choose long delays instead of short interruptions, or define a specific operation time for certain appliances (e.g. dishwasher).

Another method to control the consumption peaks of electrical boilers is also used. They propose a centralized control which acts on the boiler's thermostat, increasing the water temperature so that a larger amount of energy is stored before the high consumption periods so the user can have enough hot water during these periods.

Other initiatives detail energy-demand control strategies which can be applied to different domestic loads, taking always into account that the user can be reluctant to introduce in his/her home an external control system. The strategies are based on switching-off the loads during peak periods and on using intelligent thermostats and a centralized control of water boilers.

3.2.2 Indirect Control

The use of controllers which analyse the mains frequency and switch on/off devices depending on variations of this frequency is another option. It defines as candidate devices for this kind of control those which are used in thermal applications (heating/cooling), which allow a certain degree of flexibility in their consumption. It is focused mainly on the refrigerator, as it is a continuous and relatively constant load, with a reasonable storage time. Therefore, they implement a control which changes the operation point of the thermostat depending on the mains frequency.

Another possibility is to use a management scheme which reduces the load peaks based on four main functions, which are activated each time that the user turns on a device:

1. A planner, which calculates the best way of carrying out an action minimizing the consumption, taking into account the available loads that can be optimized (washing machine, dishwasher, dryer).
2. Energy-saving, which manages loads (lamps) according to timers and sensors.
3. A graphical interface which shows the status of each device.
4. Regular use: it guarantees that the devices operate correctly.

The topology of the structure allows several functions to work in parallel. This system works properly as long as a suitable tariffication service and enough optimizable consumption are available, and as long as the user is ready to sacrifice some comfort.

Another option is a controller which carries out home-level load shedding. The system is based on a microcontroller which controls the on/off switching of the various devices. The controller performs the necessary actions when it receives the control order, which may come from:

1. A signal sent by the network manager.
2. A clock which discriminates the peak consumption periods.
3. The overflow of a consumption level set by the user.

The priority of the loads to be delayed is defined by the user, as well as the duration of the interruption.

A control algorithm which allows shifting the operation of domestic loads in order to match several predefined demand profiles. They classify the loads according to the following features:

1. The calculation step for the load monitoring.
2. The power it needs to operate for each step of the calculation.
3. Priority of use, defined by the impact of the load shift.
4. Time that the load can be shifted with minimal effects.
5. Availability for shifting the load, taking into account how long it has been from the last shifting.

The algorithm shifts the loads according to the instantaneous demand.

A home management system which takes into account the global home situation and the consequences of the actions can be also taken into account. The system comprises the following steps:

1. It gathers the data (sensors, status of devices, electrical prices, etc.) and generates the current scenario.
2. It classifies the current scenario taking as a reference those coming from a database of predefined scenarios.
3. It analyses the actions that can be done in that scenario.
4. It adds these actions to the scenario, obtaining a virtual scenario.
5. It compares the virtual scenario with the actual one. If it is better (higher comfort, less consumption, etc.), it performs the actions.

A home energy-management system using a fuzzy controller can be used too. The system is made of a central unit which communicates with the device controllers. The control is implemented in the following three units:

1. Load models: they are needed in order to calculate the hourly home consumption and to design load-shifting strategies.

2. User interface: it allows to introduce the preferences for the devices and to communicate their status.
3. Load-shedding algorithm: it determines the shift of the loads based on the price, load, temperature and user preferences. It determines the reference temperature for devices such as thermostats and air-conditioning.

3.3 Interdependency's between the Middleware and Supervisory Control

Supervisory control and the middleware are inextricably linked and the information required by the Supervisory control module will retrieve its' information through the middleware. Supervisory control systems in plants must acquire data without any loss and react for state changes. Some of state change should be reacted in a real-time manner, while others may be notified in a best-effort manner. To implement a middleware that works as a server in supervisory control systems in an acceptable cost. The value the data freshness which means how much time has passed from the occurrence of the data. With rules using only the latest data, the Eventbased Communication Agent mechanism realizes time-critical reactions as firm real-time tasks. In addition to that, the rules trigger best-effort notification which is realized as a soft real-time task.

The middleware will manage and handle all of the communication within the ENCOURAGE system; therefore there is significant overlap with the middleware and each other component of the Encourage Architecture. The middleware will be aware of continual changes from all the different component of the system and will allow information flow; the Supervisory control module will make decisions based on the information made available from the middleware from various other sources, for example the amount of surplus electricity, current usage and current household setting etc. will all be available through the middleware. The ENCOURAGE Supervisory Control algorithms will allow seamless automated control decision be taken based on predetermined rules based on many influences both external and internal.

The Open Systems Interconnections (OSI) architecture is a standard reference model for networked systems. The proposed architecture is based on this model; central to it is the abstraction of a virtually collocated system, where information exchange between application components is supported at the level of messages exchanged between seemingly local components. This abstraction is provided by the middleware, which hides the details of a networked system such as IP addresses, network protocols, data formats, and computational resources[4]. Components can be identified using application specific content instead of network addresses and ports. They can exchange information on a regular basis, as information push whenever updates are available, or as pull on demand by an information consumer. Hardware or software can be added or removed while

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the system is running, and the designer need not deal with issues like starting up computers in an appropriate order. Also, clocks are aligned and all sensors and other information is automatically time-stamped. These features correspond to the Session and Presentation layers. Utilizing the abstraction of a virtually collocated system provided by middleware, a system designer can focus on algorithmic code for planning, scheduling, control, adaptation, estimation, or identification.

3.4 Algorithm Approach

3.4.1 Fully automatic algorithms

The function of the load management algorithm consists of generating the operating orders for each of the manageable loads integrated into the domestic environment. These orders indicate the switch-on moment for each domestic appliance (day/month/year/hour/minute). To perform this, the algorithm uses information from the features of the domestic appliances, the priorities and preferences of use established by the user, and the prices and consumption limits laid down by the contracts.

The algorithm positions the operation of each of the domestic appliances to minimize energy expenditure, bearing in mind how electricity prices are evolving and adhering at all times to the limits on the level of usable power, as well as the levels of priority and preferences of use established by the user.

The steps followed to reach the optimum solution are explained below:

1. Firstly, the domestic appliances are ranked according to their priority, so that the algorithm will start considering first the domestic appliances with the highest priority (the reason is that the moment of operation of a domestic appliance is naturally determined by the moments of operation of the other domestic appliances with higher priority).
2. Once ranked, the domestic appliances will be positioned for operation purposes while minimizing energy cost and complying with the restrictions imposed. To carry out this process, a check is first made to see whether the domestic appliance in question is on or not:
   - If it is already functioning when the algorithm kicks in, it is regarded as a time restriction and the costs associated with it are evaluated by means of function developed.
   - If the domestic appliance in question is switched off when the algorithm kicks in, a call is made to the function and it results are used to evaluate the function, which returns the switching on moment for the domestic appliance with a minimum energy cost.

3. This operation is repeated in accordance with the number of domestic appliances that are in the system. Once they have all been considered, the total costs are calculated and the nucleus of the optimization algorithm is exited.

3.4.2 User-centred algorithms

The user-centred algorithm is needed for a home energy-demand management system that is centred on the end user. His feel of comfort will improve if the user has control on the energy-demand management system. At first, he needs to have in sight on his current energy usage.

A photo display can be used show the current energy usage, which is input for the end user to change his usage pattern or give commands to the system to optimize the energy demand without loss of comfort in an intuitive way. First the user needs to get a general in sight in its daily energy consumption, see Figure 3.

Figure 3.

In Figure 4 the energy consumption is given per group of devices. The user can act on this information and give commands to reduce power consumption.

Figure 4.

The photo display is using a web interface to get information on the power consumption from the plug wise network. The same information can also be displayed on a web enabled TV set.

3.5 Define user controls for generation owned by one and shared by several users

The manager (Utility) of the Grid will maintain overall control of the **Production** Network (Grid) and the actions as a result of Production events across the network. The ENCOURAGE Platform will allow for the dynamic control of "oversupply" diversion or other key events across the system. In terms of controlling the distribution, minimal amount of localised control will be allowed to the end-users (enduser override for clothes dryers or washing machines etc.) / owners of Grid micro production units, this is in order to ensure a foolproof management infrastructure the ENCOURAGE Platform needs proactive management by key production stakeholders.

The defined algorithms will allow the Utility a real-time view of all the **Production, Usage** and **Cost** metrics across the network and will, for automated actions be based on predictive and current situations. Complexities abound across the transmission and distribution infrastructure, with inherent interactions between continuous dynamics and discrete events. Power systems should therefore be modelled as large-scale hybrid dynamical systems, where the continuous dynamics are best represented by differential-algebraic models.

3.6 Examples of Household appliances with variable energy consumption

Appliance	Description

Cooker	Various heat settings will result in different energy consumption
Dimmer Lighting	Dimmer lights oppose to standard lighting will effect energy consumption
Freezer	Altering the temperature of the freezer will have direct effect on energy
Heating System	High heating settings will have a knock on effect on energy consumption
Microwave oven	Altering the temperature of the oven will have direct effect on energy
Dishwasher	Dishwasher on settings like economy wash will help energy consumption
Fridge	Altering the temperature of the fridge will have direct effect on energy
Washing Machine	washing machine on settings like economy wash will help energy consumption
Toaster	Alteration of the heat will cause a larger energy consumption
Shower	Different settings for heat and power will contribute to an increase in power consumption

3.6.1 Examples of Household appliances with a defined (on/off) energy consumption

Appliance	**Description**
Standard Lighting	Lighting will be either in a state of on or off , resulting in am energy consumption or not
Television	Will be in a state of on/off
Dvd	Will be in a state of on/off

PC/Laptop	Will be in a state of on/off
Kettle	Will be in a state of on/off

3.7 Scenarios based on T2.2 Supervisory Control High Level Requirements

This section provides an overview of scenarios collected, each scenario has a description of its intended functionality.

Improvement of consumption is a must

Users: Residential and commercial prosumers, building managers.

Services: energy management

Description: The owner of the residential or commercial building would like to have energy consumption levels to a minimal. The owner will get information about all deviations from the expected energy consumption. The user will then in turn depending on their preferences will get notified by email/sms about this deviation.

The system shall monitor real-time disaggregated consumption
Users: Residential and commercial prosumers, building managers

Services: monitoring and visualization and reporting

Description: The owner of the building would like to have access to real-time information of their building about the consumption of energy in the house/building, each appliance must be accessed and the individual energy consumption relating to each appliance displayed. Instant values will be displayed as the owner requests, the values will be automatically refreshed at pre-defined period.

The system should provide basic (on/off)for individual appliances
Users: Residential and commercial prosumers, building managers

Services: monitoring and visualization and reporting

Description: The state of an appliance should be easily accessible when requested by the owner. For devices where on/off is not applicable a smart socket may be used. A device in a state of on/off makes the visualisation display of the device that bit easier for the user to understand and clears up any discrepancies.

The system needs to monitor external influences
Users: energy manager
Services: Control of applications
Description: external factors need to be taking into consideration when dealing with rules based on devices within the home or building , external temperatures will affect the adjustment of temperature within the buildings. If external temperatures exceed x temperature the heat in the house cannot be automatically increased , however to burn off excess energy if the temperature is lower < x temperature the temperature within the building may be risen to a predefined temperature to burn off energy.

To ensure the local surplus is used locally
Users: energy manager
Services: ensure energy is not sent back to the grid
Description: In the ENCOURAGE platform it is important when possible that no energy goes back to the grid ,if surplus energy is present locally then it is better for this surplus energy to distributed between buildings and used as efficiently as possible.

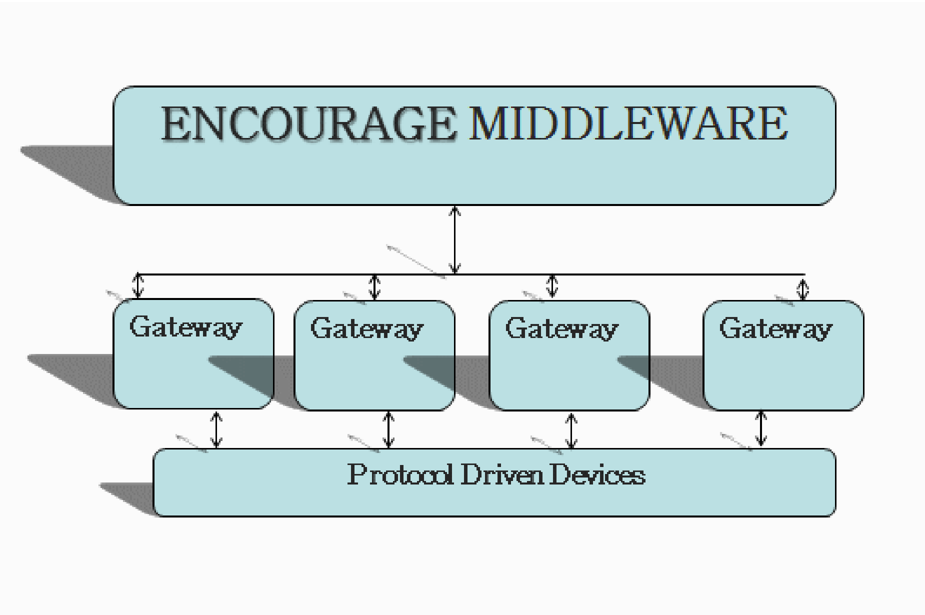
To turn off lights using motion sensors/sound detectors
Users: devices
Services: ensure energy is needlessly used
Description: Energy consumption can be increased or decreased depending on the defined set of rules, motion sensors will detect movement and upon that movement will immediately effect the performance of devices. Sound detectors likewise have a carry on effect on devices and can trigger devices to turn on or off. If surplus energy is present and needs to be discarded these devises can be turned off so they will not affect the device which is required to used the surplus energy.

The system should allow for certain devices to define their own constrains/critical setpoints
Users: residential
Services: incorporate devises own constraints
Description: Devices which are constantly altered and have no set points only a max and min have to be allowed act as they do and need to be captured as their energy consumption differs from time to time, an example of this is altering the temperature in a cooker or dimmer lights.

To use surplus energy to recharge an UPS system
Users: Energy manager
Services: Use up surplus energy so grid is not effected
Description: Surplus energy plays a massive factor in the Encourage platform, instead of going back into the grid the surplus energy will be used to recharge the UPS system, and then if surplus energy still remains, surplus energy will be used up locally as describes above,

3.8 Definition Single Source Controller

The ENCOURAGE project will allow the use of numerous Gateways from various suppliers which will act as single source controllers in each location. It is intended to publish a standard interface protocol based on one of the following standards, SEP 2.0, CIM or IEC. The ENCOURGAE Architecture working group is currently examining each protocol with a view to choosing the best solution. Gateway manufacturers will then be ENCOURAGEd to developed their firmware to incorporate an output that will connect directly to the ENCOURAGE middleware. This approach allows for any vendor hardware to connect to the ENCOURAGE platform through use of an standardised open protocol API.



3.9 Definition of efficient distributed system for data

The Encourage platform intends to build a system for data sharing that appears as a centralised system but is actually physically distributed among large set nodes. The shared data can be accessed by many remote individuals in two different modes, for reading and writing, and can be spread all over the network with redundancy. The level of access to data will differ from each user. The system should provide security without requiring physical protection and continuous administration, typical of centralised server environments. The system must be robust against active adversaries who can break in and compromise one or more nodes collecting their content. At the same time, the system is robust against passive adversaries, able to intercept the data moving through the network. Encryption techniques are to be used for data moving between the nodes of the system. However, as the data always moves locally, reallocated between nodes that are provably in close proximity, the use of encryption when it is sent over the network is not a research issue and can be accomplished without the need of any centralised authority. A distributed system consists of a collection of autonomous computers, connected through a network and distribution middleware, which enables computers to coordinate their activities and to share the resources of the system, so that users perceive the system as a single, integrated computing facility.

Centralised System Characteristics

- One component with non-autonomous parts
- Component shared by users all the time
- All resources accessible
- Software runs in a single process
- Single Point of control
- Single Point of failure

Distributed System Characteristics

- Multiple autonomous components
- Components are not shared by all users
- Resources may not be accessible
- Software runs in concurrent processes on different processors
- Multiple Points of control
- Multiple Points of failure

Common Characteristics

Certain common characteristics can be used to assess distributed systems

Resource Sharing

- Ability to use any hardware, software or data anywhere in the system.
- Resource manager controls access, provides naming scheme and controls concurrency.
- Resource sharing model (e.g. client/server or object-based) describing how resources are provided, they are used and provider and user interact with each other.

Openness

Openness is concerned with extensions and improvements of distributed systems.

- Detailed interfaces of components need to be published.
- New components have to be integrated with existing components.
- Differences in data representation of interface types on different processors (of different vendors) have to be resolved.

Concurrency

Components in distributed systems are executed in concurrent processes.

- Components access and update shared resources (e.g. variables, databases, device drivers).
- Integrity of the system may be violated if concurrent updates are not coordinated.
- Lost updates
- Inconsistent analysis

Scalability

- Adaption of distributed systems to accommodate more users
- Usually done by adding more and/or faster processors.
- Components should not need to be changed when the scale of a system increases.
- Design components to be scalable

Fault Tolerance

Hardware, software and networks fail

- Distributed systems must maintain availability even at low levels of hardware/software/network reliability.
- Fault tolerance is achieved by
    - recovery
    - redundancy

Transparency

- Distributed systems should be perceived by users and application programmers as a whole rather than as a collection of cooperating components.
- Transparency has different dimensions that were identified by ANSA project (now part of an ISO standard).
- These represent various properties that distributed systems should have

Access Transparency

Enables local and remote information objects to be accessed using identical operations.
Examples: File system operations in NFS (Network File System),Navigation in the Web,SQL Queries

Location Transparency

Enables information objects to be accessed without knowledge of their location.
Example: File system operations in NFS, Pages in the Web, Tables in distributed databases.

Concurrency Transparency
Enables several processes to operate concurrently using shared information objects without interference between them.
Example: NFS, Automatic teller machine network, Database management system

Replication Transparency
Enables multiple instances of information objects to be used to increase reliability and performance without knowledge of the replicas by users or application programs.
Example: Distributed DBMS (database management system), Mirroring Web Pages.

Failure Transparency

- Enables the concealment of faults
- Allows users and applications to complete their tasks despite the failure of other components.
- Example: Database Management System

Migration Transparency

- Allows the movement of information objects within a system without affecting the operations of users or application programs
- Example: NFS, Web Pages

Performance Transparency

- Allows the system to be reconfigured to improve performance as loads vary.
- Example: Distributed make.

Scaling Transparency

- Allows the system and applications to expand in scale without change to the system structure or the application algorithms.
- Example: World-Wide-Web, Distributed Database