DTU Library

Overview of Simulation Tools for Smart Grids

Bindner, Henrik W.; Marinelli, Mattia

Publication date:
2013

Document Version
Publisher's PDF, also known as Version of record

EERA
JOINT PROGRAMME DELIVERABLE

EERA Joint Programme on *Smart Grids*

Sub-Programme 2
Energy Management

D2.1 Overview of Simulation Tools for Smart Grids

May 2013

EERA Joint Programme on Smart Grids

Sub-Programme 2
Energy Management

D2.1 Overview of Simulation Tools for Smart Grids

Doc Version: 03
Last modification date: 06.05.2013

Editors: H. Bindner; M. Marinelli

Authors

Name	Last name	Organization	Country
Henrik	Bindner	DTU	Denmark
Mattia	Marinelli	DTU	Denmark
Diana	Moneta	RSE	Italy
Dogan	Gezer	Tubitak	Turkey
Graham	Ault	Univ. of Strathclyde	UK
Hans	De Neve	VITO	Belgium
Inaki	Laresgoiti	Tecnalia	Spain
Irina	Oleinikova	IPE	Latvia
Knut	Samdal	SINTEF	Norway
Koen	Kok	TNO	Netherland
Viviana	Cigolotti	ENEA	Italy

Executive summary

The focus of the Energy Management sub-programme is on the optimization of the management of distribution networks in presence of Distributed Energy Resources (DER) and load control with an energy and market perspective. Technical and economic scenarios will be considered for the active distribution network development, taking into account the most important smart grids features, i.e., resilience to generation and load variability, demand response, energy balance optimisation, grid loss reduction and optimal asset management. Specific attention will be given to all ICT implications.

The main aim of this report “D2.1 – Overview of Simulation Tools for Smart Grids” is to provide an overview of the different simulation tools available, i.e. developed and in use, at the different research centres. Required new tool capabilities are identified and extensions to the existing packages are indicated.

An analysis of the emerging power systems challenges together with a review of the main topics regarding smart grids is provided in **Chapter 1**.
The requirements for the simulation tools and the list of available tools in the different research centres and their main characteristic are reported in **Chapter 2.**
The main aspects of the different tools and their purpose of analysis are listed in **Chapter 3** along with the main topics concerning the new requirements for tools in order to allow a proper study in the smart grid context**.**
Gaps capabilities and model consolidation of the analysed tools are reported in **Chapter 4.**
A bibliography is provided in **Chapter 5.**
A comprehensive comparative table is reported at the end of the report in the **Annex**. An analysis of each tool is provided as well.

Acknowledgements

As outlined in the European Strategic Energy Technology Plan (SET-plan), energy technologies will be crucial to successfully combat climate change and to secure world and European energy supply. Achieving Europe 2020 and 2050 targets and visions on greenhouse gas emissions, renewable energy and energy efficiency will require the deployment of more efficient and new technologies.
In this framework, fifteen leading European Research Institutes have taken up the challenge to found the European Energy Research Alliance (EERA).
The key objective of the EERA [http://www.eera-set.eu/home] is to accelerate the development of new energy technologies by conceiving and implementing Joint Research Programmes in support of the Strategic Energy Technology (SET) plan pool and integrate activities and resources, combining national and Community sources of funding and maximising complementarities and synergies.

The EERA Joint Programmes constitute strategic, permanent collaborations between major research organisations and institutes forming a virtual centre of excellence. In response to the EU’s SET-PLAN, the Joint Programmes implement the need for better coordination among Member States, maximising synergies and identifying priorities for future funding.

In 2009, the first four EERA JPs have been prepared, after their approval by the EERA Executive Committee and launched in the occasion of the SET Plan Event held in Madrid in June 2010: Photovoltaic, Wind, Geothermal, and **Smart Grids**.
In the occasion of the SET Plan Event held in Brussels in November 2010, the following JPs have been launched: Bio Energy, Carbon Capture and Storage, and Materials for Nuclear. During the SET Plan

Conference in Warsaw, November 2011, the following JPs were officially launched: AMPEA (Advanced Materials and Processes for Energy Application), Concentrated Solar Power, Energy Storage, Fuel Cells and Hydrogen, Ocean Energy and Smart Cities.
More recently, other two new EERA JPs have been approved and officially launched: Economical, Environment and Social Impacts, and Shale Gas.

The European Energy Research Alliance (EERA) Joint Programme on Smart Grids, that is coordinated by RSE with the support of ENEA from Italy, by means of an extended cross-disciplinary cooperation involving many Research and Development (R&D) participants with different and complementary expertise and facilities, aims at addressing in a medium- to long-term research perspective, one of the most critical areas directly relating to the effective acceleration of smart grid development and deployment [www.eera-set.eu/index.php?index=21].

At present, 19 research organizations from 16 different European countries are participating in the JP on Smart Grids; the incorporation of 12 additional research institutes as associate participants has also been accomplished.
Present Participants are: RSE, TNO, VITO, AIT, JRC-IE, LABORELEC, TUBITAK, INESC/LNEG, IPE-FEI, CEA, ENEA, DTU, VTT, IWES, TECNALIA, SINTEF, IPE-IEN, University of Strathclyde, and CRES.

In terms of human resources, the JP on Smart Grids gathers together a minimum guarantee R&D effort summing up to more than 100 person years/year, owing to the significant increase associated with new participants' incorporation that took place at the beginning of 2011. To meet the expected goals and results of the JP R&D activities, all participants agreed to teamwork and to facilitate the access to their facilities and laboratories to researchers from the other participants.

The aforementioned research organizations acknowledge their national funding organizations and their nationally supported smart grid projects which have been instrumental for the achievement of the results of the foreseen research activity, a summary of which are reported in this deliverable.

We would like to thank the members of the external "Peer Review Team", and in particular, Chavdar Ivanov (ENTSO-E), Rainer Bacher (Bacher ENERGIE AG, Switzerland), and Steffen Schütte and Astrid Niesse (OFFIS, Germany) for their comments and valuable suggestions regarding this report.
We would also like to express our gratitude to Graeme Burt and Damien Frame (Strathclyde University, UK) for scrutinizing the text.

Copyrights and legal notice

For further information, please contact the Joint Programme Coordinator: Luciano.Martini@rse-web.it or the EERA member of the Secretariat: Massimo.Busuoli@enea.it.

Table of contents

1 GENERAL BACKGROUND AND INTRODUCTION TO EERA

1.1 The European Energy Research Alliance (EERA)

EERA is a European Energy Research Alliance founded by ten leading European Research Institutes. The key objective of the EERA is to accelerate the development of new energy technologies by conceiving and implementing Joint Research Programmes in support of the Strategic Energy Technology (SET) plan by pooling and integrating activities and resources, combining national and community sources of funding and maximising complementarities and synergies.
EERA has launched 15 Joint programs: Photovoltaic, Wind Energy, Geothermal Energy, Smart Grids, Materials for Nuclear, Carbon Capture and Storage (CCS), Bioenergy, Marine Energy and Concentrated Solar Power (CSP), Smart Cities, Energy Storage, AMPEA (Advanced Materials and Processes for Energy Applications), Economical, Environment and Social Impacts, and Shale Gas.

1.2 EERA JP on Smart Grids (SG)

EERA-SG is a Joint Program of the European Energy Research Alliance. The Programme was officially launched at the SET Plan Conference in Madrid (June 2010).
At present, 19 research organizations from 16 different European countries are participating in the JP on Smart Grids; the incorporation of of 12 additional research institutes as associate participants has also been accomplished.
Present Participants are: RSE (IT), ENEA (IT), TNO (NL), DTU (DK), VITO (BE), VTT (FI), SINTEF (NO), AIT (AT), TECNALIA (ES), IWES (DE), JRC-IE (NL), LABORELEC (BE), TUBITAK (TR), INESC/LNEG (PT), IEN (PL), IPE (LV), CEA (FR), the University of Strathclyde (UK), and CRES (GR).
Furthermore, several other institutions have expressed interest in joining the JP.

The following Sub-Programmes (SP) make part of the Smart Grids Joint Programme:

- SP1 - Network operation,
- SP2 - Energy management,
- SP3 - Control system interoperability,
- SP4 - Electrical storage technologies,
- SP5 – Transmission Networks

1.3 Smart Grid application areas

The term Smart Grids refers to the progressive evolution of the electricity network towards “a network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both, in order to efficiently deliver sustainable, economic and secure electricity supply” [1]. In the report of the European Commission Task Force for Smart Grids Expert Group 1 [2] , a smart grid is defined as follows:
“A Smart Grid is an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety.”
Smart grid is basically a combination of the grid control technology, intelligence information technology and intelligence management of generation, transmission and distribution.

2 INTRODUCTION

2.1 Systems with Renewable Energy

Long-term energy security depends on the continuing availability of fossil fuels and their potential substitution by renewable energy sources. Coal and gas may well dominate the global primary energy supply for the rest of this century if no special effort is made to promote renewable sources. However, for many countries energy security concerns are accompanied by a preference for renewable options, which can reduce the dependence on imported oil and gas, as well as helping to meet environmental policy objectives. Nevertheless there is a clear focus in the European Union on promoting low-carbon generation technologies and renewable sources, with new and binding targets of 20% of power generation from renewable sources by 2020 [3].

In order to manage this new amount of renewable and generally uncontrollable generation, the electric distribution power systems are thus evolving from *passive* to *active* systems, where the word *active* refers to the fact that loads and both conventional and renewable distributed generators can play a significant role into the electricity market and in the control of the system.

The traditional concept of the power system with energy generated by few central and large power plants is changing to a concept of a system that also contains many distributed medium and small scale generators. Some types of these generators embedded into the network are fed by renewable sources like wind and sunlight. The main drawbacks are their stochastic behaviour and uncontrollable output. This means having, for example, maximum production during minimum demand period or excess of generation in congested parts of the electric network, thus causing technical constraints in some critical sections of the grid [4]. The presence of storage systems could, for example, grant a relief in congested areas of the electric system and permit to operate and dispatch renewable generation with overall optimised goals. All these challenges require study and research activities, for which proper simulation tools need to be realized and validated in the field.

2.2 Power Systems Operation

The function of an electric power system is to convert energy from one of the naturally available forms to the electrical form and to transport it to the points of consumption. Here the energy is generally converted into other forms depending on the purpose (mechanical, thermal, etc...). The main advantage in the use of the electrical energy is that it can be easily transported and controlled with a high degree of efficiency and reliability [5]. The classical approach to a properly designed and operated power system should, therefore, meet the following requirements:

- The system must be able to follow the continually changing (but fortunately quite predictable) load demand as, unlike other types of energy, electricity cannot be stored efficiently in sufficient quantities.
- The system should supply with minimum ecological impact and at minimum cost.
- The quality of power supply must meet certain standards, identified by a constancy of frequency and voltage and a high level of reliability.

The main actors of the power systems are currently the power stations (‘bulk generation’). Conventional power stations typically use synchronous generators with a highly predictable supply of “fuel”, be this hydro (when based on substantial water reservoir otherwise it can be also intermittent), nuclear, coal, oil, gas or other resources. In addition to providing electrical energy to the network they also provide a number of other services, as described below. The operation of a network with conventional generation has been described in several books and publications so here only a brief overview will be provided [6].

Scheduled Power Generation: Large conventional power stations can be scheduled for a certain constant power level, provided that there is input energy available. The schedule for individual generators may be decided by the system operator to suit the load demand and to take into accounts overall economics and system security constraints. In unbundled electricity markets, the generators are scheduled as a consequence of the day-ahead market decisions, within boundary conditions set by the TSO, and with the system operator arranging for balancing power to compensate for any power shortages or excesses.

F/P Control (Frequency Power Control): In order to ensure that the network is secure in the event of a trip of a major power station or transmission resource, the total generation resource connected will be increased to provide a margin above the forecast maximum demand (spinning reserve). Some of the generators will not be operating at their maximum possible output during normal conditions. Typically, three levels of control ensure that constant system frequency is maintained and the power balance is restored:

- The *primary control* is an automatic function of each generator governor in the network to quickly adjust the output of the unit in reaction to the frequency change, in order to restore the balance between supply and loads. The balance is restored, but the frequency may deviate from its original value.
- The *secondary control* is a centralized automatic generation control (AGC) function to regulate the output of one or more generators such that the frequency returns to its nominal value.
- The *tertiary control* loop, generally manually operated in the TSO control room, reschedules the power stations in order to restore the operating margins in the power system.

Inertial Response: Inertia refers to the stored rotational energy in the generator and it reflects the degree to which rotating masses oppose changes to the power frequency. The rate of change of frequency after a mismatch in the demand and supply balance is related to the system inertia. The generators, including their prime movers, typically have a large rotating mass, which provides a steadying influence on the generator voltage phase angle. This increases the time constant of swings and disturbances in the ac network and it stabilizes the frequency response to changes in the demand/supply balance.

V/Q Control (Voltage Reactive Power Control): The excitation control enables the generator to control the AC voltage at its terminals through the absorption or generation of reactive power. Typically, this vital role for the network is performed through an Automatic Voltage Regulator (AVR) which will have a steady-state control target as well as a sloping characteristic.

PSS (Power System Stabilization): Some of the generators may be fitted with power controllers (power system stabilizers, which act through the excitation system) designed to damp power swings in the network. This can be particularly useful when the network has distinct areas with large concentration of loads and generation interconnected by long weak lines.

Fault Current Contribution: During a fault in the AC network the generators continue to provide current into the AC network. The fault current that may be experienced by switchgear and other equipment in the network is often one of the key dimensioning design factors, and in some cases it is necessary to introduce measures aimed at reducing the fault current. On the other hand most types of conventional fault protection used in an AC network depend on the presence of high amplitude current during fault conditions for its correct operation.

Fault Ride Through: In the event of a fault in the AC network, the generators may experience large over-currents and power swings both during the fault and after its clearance by the appropriate switchgear. The conventional generators are designed with these stresses in mind and continue to be connected to the network during and after the fault, such that the power supply system can return to normal conditions immediately after the disturbance. Generators very close to a fault are allowed to trip if the critical fault clearance time of that unit is not met, but tripping is then limited only to typically one unit/power plant only, so that the power supply system, as a whole, is not jeopardized.

Market operation: The operation of the power system is becoming increasingly dependent on different markets. Many of the issues mentioned above are now being traded e.g. as so-called ancillary services. It is therefore very important that markets are designed in an efficient way so as to enable economic operation of the power system while not jeopardizing the security of supply. It is particularly important that the market structures enable all available resources to be integrated in the markets on equal terms.

Renewable and non-dispatchable generation can in principle be used for the provision of most the previously described services, depending on the source (wind, sun...) available at a specific time. Naturally, as is also the case for conventional generation used for this purpose, the generators would then not be operated at their maximum power production capability, but instead at a reduced value. It should be pointed out that an important difference is that, in the case of curtailing of renewable energy, this 'green' form of energy gets lost, whereas in fossil power plants (and partially in hydro plants) the energy source is saved and can be used later. The "fuel" costs of the power plant do not decrease during curtailment, which causes some reluctance by DER operators towards curtailment because of lengthening of capital cost sinking plan and especially because of the incentive loss.

2.3 Smart Grids Issues

The connection of huge amounts of generation to distribution networks, which have been built with the aim of serving passive users, poses several issues regarding the safe operations of such systems. Today's grids are still predominantly based on large central power stations connected to high voltage transmission systems which, in turn, supply power to medium and low-voltage local distribution systems. However a slow change is in progress. A huge number of distributed generations such as small cogenerative units as well as domestic size or large ground photovoltaic plants are progressively being connected to the distribution network. Also from the demand perspective, it can be seen that controllable loads are being connected to the system with the capability of being shed or modulated that enables them to be comparable to generation systems. Both generation and loads will be capable of remote control capability, thus distribution grids will become active and will have to accommodate bi-directional power flows.

The European electricity systems have moved to operate under the framework of a market model in which generators are dispatched according to market forces and the grid control centre undertakes an overall supervisory role (active power balancing and ancillary services such as voltage stability). Distribution networks, on the other hand, have seen little change and tend to be operated radially with mostly unidirectional power flows and "passive" operation.

Other issues arise from the future connection of huge numbers of heat pumps, electric vehicles and other types of load to the low voltage network due to the substitution of fossil fuels with electricity. Also, the liberalization of the electricity market opens the possibility to customers to participate in trading of energy and provision of power system services. It is clear that a high level of distributed intelligence, boosted by information and communication technology, is needed in order to enable the grids to become smart. For that reason, the Strategic Energy Technologies Plan (SET Plan) identifies electricity grids as one of the critical areas that need to be addressed to prepare for a low-carbon future. The European Electricity Grid Initiative (EEGI) has been launched and will be the enabler of all SET Plan technology initiatives [7].

A smart electricity infrastructure or a smart grid is a new highly-integrated power grid based on the physical grid (Figure 1) and ICT features. Similar to some aspects of existing grids, it possesses the capability of integrating such renewable electricity as solar and wind as well as controllable loads like heat pumps or electric vehicles, however it allows the system to be operated in a more economic and efficient way. It combines with advanced sensor measurement technology, computer technology, information technology, control technology, communication technology and physical power.

Since many of the new loads come with some form of associated energy storage, such as batteries in electric vehicles and heat capacity of buildings, it is possible to exploit them to provide some flexibility to the power system, thus mitigating the impact of the increased load on the distribution system and at the same time enable them to assist in the integration of DER by timing the consumption of the components to when the RE sources provides energy. However, the variety of heat pumps, houses and EVs makes coordinated control a challenge, in particular since the primary purpose of the units cannot be compromised without the user's consent.

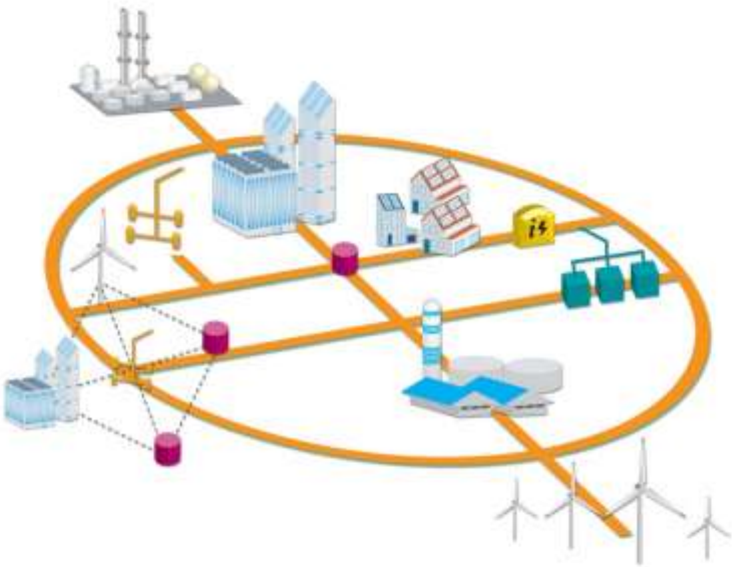


Figure 1. System operation will be shared between central and distributed generators. Control of distributed generators could be aggregated to form microgrids or 'virtual' power plants to facilitate their integration both in the physical system and in the market [1].

Different definitions of Smart Grids are given. The Smart Grid Strategic Group, SG3, defines Smart Grids as the concept of modernizing the electric grid. The Smart Grid is integrating the electrical and information technologies in between any point of generation and any point of consumption [8].

European Technology Platform Smart Grid defines smart grid as follows. A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it (generators, consumers and those that do both, that means prosumers), in order to efficiently deliver sustainable, economic and secure electricity supplies.

According to NIST (National Institute of Standards and Technology), Smart Grid is the combination of subsets of the following elements into an integrated solution meeting the business objectives of the major players, see Figure 2 [9]. Regardless of the definition of Smart Grids it is required that proper simulations tools cover these interconnected fields.

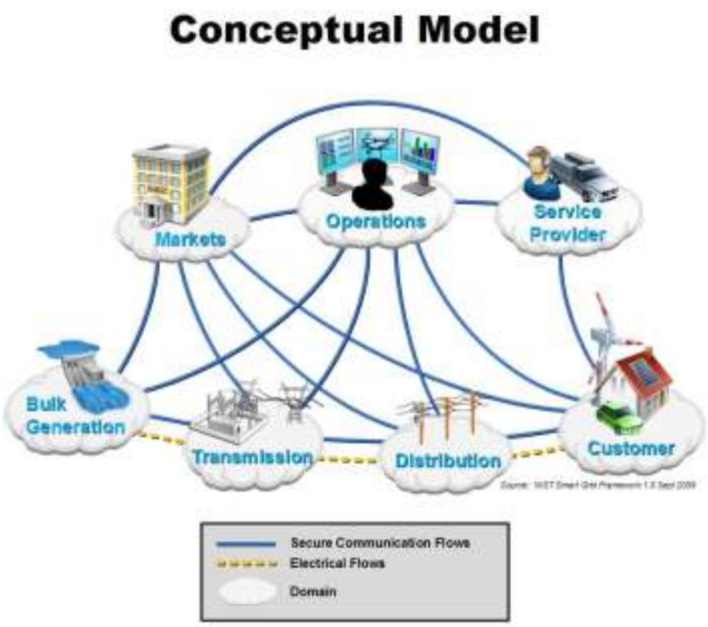


Figure 2. Conceptual model [9].

From Figure 2 the following topics can be highlighted inside the Smart Grid framework:

- Customer / Prosumer
  - Smart Consumption will enable demand response through the boosting of building automation.
  - Local Production is increasing over and over and within time will become massive.
  - Flex Homes are houses which are equipped with a home automation system that interconnects a variety of control products for heating/cooling the environment, managing the kitchen devices (such as refrigerator) lighting, shutters and blinds with a common network infrastructure.
  - Building Automation and Control System (BACS) is the brain of the building. BACS includes the instrumentation, control and management technology for all building structures, plant, outdoor facilities and other equipment capable of automation.
- Bulk Generation
  - Smart Generation will include the increased use of power electronics in order to interface originally DC sources (such as PV), or rotating machines with different operating speed (such as wind turbine and gas micro-turbine). This will offer the possibility of easily and quickly shedding extra production but on the contrary will reduce the rotating inertia of the power system.
- Power Grid (Transmission and Distribution)
  - Substation Automation & Protection is the backbone for a secure transmission grid operation. During recent years serial bus communication has been introduced (IEC 61850).
  - Power Quality and Power Monitoring Systems act in a very similar way to Quality Management Systems in companies. They are independent from Operation, Control and Management Systems and supervise all activities and assets in a corresponding grid. Therefore such systems can be used as "early warning systems" and to analyse faults and their causes.
  - The Energy Management System (EMS) is the control centre for the Transmission Grid. Today customers require an open architecture to enable an easy IT integration and a better support to avoid blackouts (e.g. phasor measurements, visualization of the grid status, dynamic network stability analysis).

- In contrast to traditional protection devices, which protect the primary equipment (e.g. transformers) from fatal fault currents, the Decision Support Systems and System Integrity Protection Schemes protect the power systems from instabilities and black-outs.
- Asset Management Systems and Condition Monitoring devices are promising tools to optimize the OpEx and CapEx spending of utilities. Condition-based maintenance, for example, allows the reduction of maintenance costs without sacrificing reliability. Furthermore they may also be used to utilize additional transport capacity due to better cooling of primary equipment, e.g. transmission lines on winter days.
- Distribution Automation and Protection: Whereas automated operation and remote control is state of the art for the transmission grid, mass deployment of Distribution Automation is only recently becoming more frequent, leading to "Smart Grids". Advanced distribution automation concepts promote automatic re-configuration features, reducing outage times to a minimum. Another step further is the use of distributed energy resources to create self-contained cells, called Micro Grids, which can possibly help to assure energy supply in distribution grids even when the transmission grid has a blackout.
- The Distribution Management System (DMS) is the counterpart to the EMS and is therefore the control center for the distribution grid. In countries where outages are a frequent problem, the Outage Management System (OMS) is an important component of the DMS. Other important components are fault location and interfaces to Geographic Information Systems.
- Important issues for the operation of the distribution network are maintaining the voltage of the grid within prescribed values and to avoid overload. These issues have until now mainly been handled through design procedures of the grid and rather conservation operation schemes. With the introduction of more embedded generation and increased loads it is important that these procedures are being re-evaluated. It is one of the areas where smart grids can have a very significant economic impact. For the optimal economic operation of the system it is essential that design procedures and the operation of the grid are adapted to include these new resources
- Smart Meter is a generic term for electronic meters with a communication link. "Advanced Metering Infrastructure" (AMI) allows remote meter configuration, dynamic tariffs, power quality monitoring and load control.

- Communication
  - Communication as a whole is the backbone of Smart Grid. Only by exchanging information on a syntactic and semantic level can the benefits of Smart Grid be achieved.
  - Security of a critical infrastructure has always been an issue. However Smart Grid solutions will see an enormous increase in the exchange of data both for observability but also for controllability. Therefore security of this data exchange and the physical components behind it will have an increased impact.
- Markets and market operation
  - During recent years more and more of the operation of the power system has been carried out through market mechanisms. This includes long term bulk energy trading as well as short term control tasks such as frequency control. The type of market is very dependent on the services that are being traded. Since the existing markets were designed prior to smart grids, there exist barriers for the integration of DER into the markets. It is one of the crucial issues that markets can be structured to easily accommodate small DER units as well as large conventional plants on equal terms.

3 SIMULATION TOOLS

3.1 Tools Requirement

The scope of a comprehensive tool for studying all the different aspects of the new smart power system under development is large. Factors influencing the requirements of the tools include the following:

- Devices variety: a huge amount and type of components need to be implemented, starting from classical rotating machines, through power converter generators, to domestic small loads (such as heating or refrigerators) capable of negative generation capabilities.
- Historically power system studies have generally been focused on the high voltage system. The increase of dispersed generation connecting to medium and low voltage networks, which often cannot be refurbished because of extra costs, requires a deep knowledge and characterization of these network levels also.
- Cogenerative units provide both thermal and electric output. Proper component MODELLING has to take care of both dynamics, because one output is related with the other. In a similar way, when studying, for example, the thermal response of a house the comfort index of the dwellers must also be taken into account. The same argument has to be taken when considering the storage system of the future electric cars, acknowledging that the car is primarily a mean of transportation and then a storage system.
- Due to the distributed nature of the DER components as well as their small individual contribution one of the main issues to study is how control can be implemented. Important issues include internal control hierarchies, how the DER units are being aggregated/de-aggregated and how the proposed solutions scale to systems with very high number participating units. The aggregation and de-aggregation of data should enable automatic setup and operation of the control system and at the same time be compatible with the requirements coming from operation of the grid such as voltage control and avoidance of congestions. The aggregation can be done either on the basis of the topology of the grid or independently of such information. The control hierarchy can also have a significant impact on how well it scales to include very high numbers of units to be coordinated and controlled.
- In modern liberalized markets, both large and small generators (renewable and fossil), transmission and distribution operators, suppliers, retailers, non-physical traders and customers can participate in in the trade of electricity.. However, the particular physics of electricity supply poses various challenges for their commercial interactions.
- Electric Vehicles could have wide-reaching effects across the electricity and transportation sectors. The benefits that result could be unevenly distributed among consumers and ratepayers. These linkages and outcomes, and their distributional consequences, must be fully captured to understand the implications of utility infrastructure investments.

Summarizing, the tools needed for the analysis of smart grids issues require:

- Capability to study the interaction between systems with several actors. For example, a DSO operating the Distribution Network interacting with an aggregator controlling a portfolio of DER units according to market signals.
- Ability to assess control schemes that enable DER to provide flexibility, taking the primary purpose as well as RE production of the units into account. The tools should be able to quantify the aggregated amount of flexibility of a large group of units
- The ability to analyse the interaction between the existing power system and (large) groups of DER units from a technical as well as market perspective.
- The ability to assess impact on local grids, taking control scheme and system level into consideration.

A tool able to deeply study the different aspects of the power systems may not be easy to find and to practically implement.

3.2 List of Tools

In Table 1 the main information regarding the tools developed within the EERA Smart Grids members are provided. The name of the tool, the developing institution and the nationality, the main users, the contact person and if the doc and xls contribution (for the template see annex) have been provided.

Table 1 – Main information regarding the tools

NAME OF THE TOOL	DEVELOPER	NATION	USER	CONTACT PERSON
LDM-SG	IPE (Institute of Physical Energetics)	Latvia	IPE	Irina Oleinikova irina@edi.lv
eTransport	SINTEF Energy Research	Norway	External user under license	Knut Samdal knut.samdal@sintef.no
Samnett				
Prodnett				
OPAL/ SAMREL				
MODERNE	University of Strathclyde	Scotland	University of Strathclyde	Graham Ault g.ault@eee.strath.ac.uk
LV Planning				
HMms				
HESA				
Probabilistic Load MODELLING				
CEEMU	TECNALIA	Spain	TECNALIA	Inaki Laresgoiki inaki.laresgoiti@tecnalia.com
VPP				
MST				
Flexibility forecasting tool				
IPSYS	DTU	Denmark	DTU	Henrik W. Bindner hwbi@elektro.dtu.dk
Flextool	VITO	Belgium	VITO	Hans de Neve hans.deneve@vito.be
Intelligator				
PowerMatcher	TNO	Holland	TNO	Koen Kok koen.kok@tno.nl
Fi.Si. (Field Simulator)	RSE	Italy	RSE	Diana Moneta diana.moneta@rse-web.it
Ma.Re.				
MONET				
SPREAD				
VoCANT				
SCUDO				

4 TYPES OF ANALYSIS AND TOOLS

In order to make a classification of the several tools provided, a comprehensive table is going to be built (see Table 8 at the end of the annex). The headers of this table are identified by the main aspects that characterize the tools, such as the voltage of study and the power calculation capabilities or the smart grid controls implemented. Detailed tables are described in the following paragraphs.

4.1 General features

The general features of the tools are listed in Table 2 and descriptions of the headers are provided below.

4.1.1 Scope of tool

This header identifies the level of voltages for the system being studied. Studying the network at different voltage levels require different library information. For example if a high voltage network is going to be studied it is important to have information regarding the components typically used in a substation, such as a breaker, a disconnector, an earth switch if the system is composed by a double busbar or single bus, tie breakers, etc…

If a medium or low voltage network is going to be studied, more information regarding the components installed for example in a MV/LV substation are required: breaker, remote controlled breaker, fuse, etc...

4.1.2 Primary Purpose of Model

This header is the primary modelling horizon time of the tool. Depending on the scope of the tool different aspects of the models have to be defined. If the focus is operational scenarios, dynamics ranging in the order of seconds/minutes are the main concern. On the contrary the planning activity is especially oriented on assessing the requirements for generation and infrastructure capacity adequacy and the possible impact on the local population and environment.

4.1.3 Model Context

The purpose of the model (balancing, network impact or market issues) can be found in this header, specifically:

- Balancing is related to primary and secondary frequency/active power and voltage/reactive power issues and spans from classical synchronous rotating machine approach, through power converter equipped generators, to Electric Vehicles and domestic load response capabilities.
- Network impact is related to studying the impact on the local grid, including power flows and voltage profiles along the feeders. Also the robustness and the stability of power systems/VPP are considered.
- Market issues refer to the structure of the market.

4.1.4 Modelling Type

This header identifies the modelling concept applied. The modelling typology can be a deterministic TS model, stochastic time series, or statistical with distributions as input and output. The time step refers to the time frame domain at which the simulations can be executed.

Table 2 – Scope of tools

BASIC INFORMATION		SCOPE OF TOOL	PRIMARY PORPUSE OF MODEL	MODEL CONTEXT	MODELLING TYPE	
Name of tool	**Developer**	**TSO/DSO level**	**Operational/ Planning**	**Market / Balancing / Network impact**	**Deterministic / Stochastic / Statistical**	**Time step**
LDM-SG	IPE (Institute of Physical Energetics)	DSO	Planning	Network impact	Deterministic / Statistical	1-5 year, (regime calc.- 1 month)
eTransport	SINTEF Energy Research	Both	Both	Market / Network impact	LP in operational module, DP in investment module an SDP versions is prototype	Time step 1 hour in operational module, years in investment module
Samnett	SINTEF Energy Research	TSO	Planning	Market / Network impact	Stochastic	
Prodnett	SINTEF Energy Research	Both	Planning	Balancing / Network impact	Stochastic	Minimum time step of 1 hour
OPAL/ SAMREL	SINTEF Energy Research	TSO	Planning	Mainly for detailed network impact, power market results are input.	Stochastic	
MODERNE	University of Strathclyde	DSO	Multi-objective planning	Network Impact - DER integration	Stochastic / Statistical	Time-Step
LV Planning	University of Strathclyde	DSO	Planning	Network Impact	Stochastic / Statistical	Time-Step
HMms	University of Strathclyde	Both	Operational market performance and planning	Market	Deterministic TS	
HESA	University of Strathclyde	DSO	Planning	Market / Network impact	Stochastic / Statistical	single point (time step to come)
Probabilistic Load MODELLING	University of Strathclyde	DSO	Could be used for day ahead operational	Market / Network impact	Statistical	
CEEMU	TECNALIA	DSO	Planning	Market	Stochastic	1 hr
VPP	TECNALIA	DSO	Operational	Network impact	Deterministic	1 hr
MST	TECNALIA	DSO	Operational	Market / balancing	Deterministic	1 hr
Flexibility forecasting tool	TECNALIA		Planning	Balancing	Stochastic	1 hr
IPSYS	DTU	DSO	Operational	Balancing / Network impact	Deterministic	60s-1h
Flextool	VITO	not relevant	Operational	Market	Statistical	
Intelligator	VITO	Both	Operational	Balancing / Network impact	Deterministic	
Power Matcher	TNO	Both	Operational	Balancing / Network impact	Deterministic / Stochastic	1 minute
Fi.Si. (Field Simulator)	RSE	DSO	Operational	Network impact	Deterministic	Time-step
Ma.Re.	RSE	DSO	Both	Network impact	Deterministic	
MONET	RSE		Planning	Market / balancing	Stochastic	

BASIC INFORMATION		SCOPE OF TOOL	PRIMARY PORPUSE OF MODEL	MODEL CONTEXT	MODELLING TYPE	
Name of tool	**Developer**	**TSO/DSO level**	**Operational/ Planning**	**Market / Balancing / Network impact**	**Deterministic / Stochastic / Statistical**	**Time step**
SPREAD	RSE	DSO	Planning	Network impact		
VoCANT	RSE	DSO	Operational	Market / Network impact	Deterministic	Time-step
SCUDO	RSE		Operational	Market	Stochastic	

From the data in the Table 2 it can be observed that:

- Focus is on distribution networks. Some of the tools include both transmission system and distribution system.
- There are an equal number of tools that are oriented towards planning and operation.
- Focus is also on network impact. It is often combined with market or balancing analysis capability.
- The simulation method is equally split between stochastic and deterministic approaches.

4.2 Economics and Sub Systems Modelled

Which subsystems of the energy systems are included in the tools and their possible interactions are listed in Table 3 along with the economics aspects. For example, considering the case of a cogenerative unit, how the thermal dynamics affect the electrical capability of the system. The economics header identifies if the simulation is a purely technical simulation or if it is calculating the impact of a particular implementation for example at the society level or on the local/global environment and if it takes into account social benefits issues.

Table 3 – Economics and subsystem modelled

BASIC INFORMATIONS		ECONOMICS	ENERGY SUB SYSTEM MODELLED
Name of tool	**Developer**	**No economic calculation / Business case / Social benefit**	**Electrical / heat / gas /other**
LDM-SG	IPE (Institute of Physical Energetics)	Business case / Social benefits	Electrical
eTransport	SINTEF Energy Research	The model calculates the least cost development plan for a given area/region	Electrical / heat / gas / cooling and biomass
Samnett	SINTEF Energy Research	Fundamental economic model which aims at maximizing socio-economic surplus.	Only the electric power system is explicitly modelled.
Prodnett	SINTEF Energy Research	Economic model which aims at maximizing socio-economic surplus.	Electrical
OPAL/ SAMREL	SINTEF Energy Research	Reliability indices including cost of energy not supplied are calculated.	Electrical
MODERNE	University of Strathclyde	Business case - trade off analysis of DER	Electrical
LV Planning	University of Strathclyde	Technical impact only at present	Electrical
HMms	University of Strathclyde	Business case	Electrical /heat
HESA	University of Strathclyde	End user costs present (FIT, feedback, grid electricity and gas costs). Societal - impact of community heating scheme	Electrical / Gas / heat
Probabilistic Load MODELLING	University of Strathclyde	Technical Impact. Societal Impact (Quantifying Behavioural Change)	Electrical / Gas / heat

BASIC INFORMATIONS		ECONOMICS	ENERGY SUB SYSTEM MODELLED
Name of tool	**Developer**	**No economic calculation / Business case / Social benefit**	**Electrical / heat / gas /other**
CEEMU	TECNALIA	Business case. Social benefit	Electrical / Gas
VPP	TECNALIA	No economic calculation	Electrical
MST	TECNALIA	Business case	Electrical
Flexibility forecasting tool	TECNALIA	Business case	Electrical
IPSYS	DTU	No economic calculation	Electrical / Gas / heat
Flextool	VITO	Business case	Electrical
Intelligator	VITO	No economic calculation	Electrical
Power Matcher	TNO	Business case	Electrical / Gas / heat
Fi.Si. (Field Simulator)	RSE	Business case	Electrical
Ma.Re.	RSE	No economic calculation	Electrical
MONET	RSE	Economic calculation / business case / social benefit	Electrical / Heat
SPREAD	RSE	Technical assessment / business case	Electrical
VoCANT	RSE	Technical assessment / business case	Electrical
SCUDO	RSE	Economic calculation / business case / social benefit	Electrical

Table 3 shows that:

- More weight is on business case analysis and the electrical system and less on societal benefits and integration of different parts of the complete energy system.
- There are, however, a number of the tools that include other parts of the energy system in particular heat and gas system.
- There are some technology performance-only tools but they are relatively few.
- With the focus on business cases the flexibility of the tools can be limited since business cases often are very specific.

4.3 Electric Grid Model

How the electrical network is modelled, how many voltage levels are taken in account and if the tool provides a load flow equation solver (full unbalance load flow or DC load flow) is reported in Table 4.

Table 4 – Electric grid model

BASIC INFORMATIONS		**ELECTRIC GRID MODEL**			
Name of tool	**Developer**	**Max number of BUS / LINES / GENERATORS / CONSUMERS / CONTROLLERS**	**No network model /DC load flow**	**Symmetrical /asymmetrical load flow**	**number of voltage levels**
LDM-SG	IPE (Institute of Physical Energetics)	600 / 1000 / 300 / 600		Symmetrical load flow	5
eTransport	SINTEF Energy Research	Limited by computer capacity	DC LF		No specific limitation
Samnett	SINTEF Energy Research	Limited by computer capacity (tested on 3000 bus bars system)	DC LF		
Prodnett	SINTEF Energy Research	Tested on systems comprising less than 100 bus bars and lines	DC LF		
OPAL/ SAMREL	SINTEF Energy Research	Limited by computer capacity (tested on Nordic power system 3000 bus bars system)		Symmetrical load flow	
MODERNE	University of Strathclyde	any distribution network		Symmetrical load flow	any distribution network
LV Planning	University of Strathclyde	any distribution network		Asymmetrical full load flow	any distribution network
HMms	University of Strathclyde	any	DC LF		
HESA	University of Strathclyde	any distribution network	Bulk Energy Flows (elec, gas, fuel, heat, co2)		any distribution network
Probabili-stic Load MODELLING	University of Strathclyde	any distribution network			any distribution network
CEEMU	TECNALIA		No network model		
VPP	TECNALIA	Same as allowed by simulation tool used		Same as allowed by simulation tool used	1
MST	TECNALIA		No network model		1
Flexibility forecasting tool	TECNALIA		No network model		1
IPSYS	DTU	memory		Symmetrical load flow	
Flextool	VITO	Not relevant			
Intelligator	VITO	Not relevant			
Power Matcher	VITO	Limited by computer capacity			
Fi.Si. (Field Simulator)	RSE	Limited by computer capacity		Symmetrical load flow	as user defines
Ma.Re.	RSE	memory		Asymmetrical full load flow	2
MONET	RSE	memory	No network model		
SPREAD	RSE	memory		Symmetrical load flow	2
VoCANT	RSE	memory	AC OPF	Symmetrical load flow	3
SCUDO	RSE	memory	No network model	Symmetrical load flow	

Observations from Table 4 provide that:

- The power system in case, explicitly modelled, is either modelled using a DC load flow or a symmetrical AC load flow. The tools, mainly for transmission system analysis, are implementing DC load flows algorithms.
- There are few asymmetrical load flow capable tools.
- Most of the tools are capable of analysing (adequately) large systems.

4.4 Smart Grid Control

The control of the DER units is an essential part of investigating the performance of smart grid issues as already stated in the preceding sections. The typology of control and the application cases are reported in Table 5. The control model of the simulation tools is characterized by either explicit control of the DER units or implicit e.g. in the form of optimization where the control of the units is implicitly assumed. The control can be modelled with a different granularity e.g. on the basis of the individual appliances (such as dishwasher, fridges, heating devices, etc…) or on the basis of lumped/aggregated behaviour. Depending on the entity controlled in the simulation, the focus can be on the house, seen as a set of domestic devices, or on the substation, seen from the connection point of the MV/LV transformer side. Further, the control will include the physical setup or have an aggregated point of view. The control options span from direct, indirect or market based ones.

Table 5 – Smart Grid control

BASIC INFORMATIONS		**SMART GRID CONTROL**			
Name of tool	**Developer**	**Control model**	**Appliance / Microgrid**	**Local / aggregated**	**Direct / indirect / market based**
LDM-SG	IPE (Institute of Physical Energetics)	Optimization	Microgrid (house)	Local	
eTransport	SINTEF Energy Research	-	-	-	-
Samnett	SINTEF Energy Research	-	-	-	-
Prodnett	SINTEF Energy Research	-	-	-	-
OPAL/ SAMREL	SINTEF Energy Research	-	-	-	-
MODERNE	University of Strathclyde	OPF and DER location curtailment	DER	Flexible	Direct
LV Planning	University of Strathclyde	Flexible	Flexible	Flexible	flexible
HMms	University of Strathclyde			Flexible	market based control
HESA	University of Strathclyde	DER location and dispatch	Flexible	Flexible	flexible
Probabilistic Load MODELLING	University of Strathclyde	Not applicable			
CEEMU	TECNALIA	No Control model			
VPP	TECNALIA	Load flow model		Individual units	
MST	TECNALIA		Microgrid	Both	market based control
Flexibility forecasting tool	TECNALIA		Appliance	Aggregated	market based control

BASIC INFORMATIONS		**SMART GRID CONTROL**			
Name of tool	**Developer**	**Control model**	**Appliance / Microgrid**	**Local / aggregated**	**Direct / indirect / market based**
IPSYS	DTU	No particular control assumed, Flexible	Microgrid (house)	Individual	
Flextool	VITO	Optimization	Appliance	Aggregated	
Intelligator	VITO	Market based control	Appliance	Aggregated	market based control
Power Matcher	VITO	No particular control assumed, Flexible	Appliance	Aggregated	Direct / market based control
Fi.Si. (Field Simulator)	RSE	No particular control assumed, Flexible	Microgrid	Individual	Direct
Ma.Re.	RSE	No particular control assumed, Flexible	EV charging station	Individual	
MONET	RSE	No particular control			market based control
SPREAD	RSE	Flexible	Appliance	Individual	Direct
VoCANT	RSE	Optimization	Appliance	Both	Direct
SCUDO	RSE	implicit	Appliance	Aggregated	market based control

The table on smart grid control, Table 5, indicates that:

- Only a few of the tools are optimizing tools i.e. trying to optimize the operation of the DER units in view of a particular operating strategy.
- The majority of the tools do not have a particular control strategy but only implement an interface to the components.
- Most of the tools are analysing performance based on an appliance control level, but some of them are treating the aggregated behaviour of the appliances.
- Most of the tools have indicated a particular interface/way of controlling the units i.e. either directly or market based.
- None of the tools are suitable for analysing indirect control.

4.5 Software Availability

The availability (free, under license or for internal private use only) of the software and the platform on which has been developed is reported in Table 6. Whether the tool also uses libraries or other software components is indicated. From the table it can be seen that most tools are windows based and can run stand alone. Almost all of them provide data exchange via xls or csv files.

Table 6 – Software availability

BASIC INFORMATION		**Software characteristics**				
Name of tool	**Developer**	**Free / Commercial**	**WIN / MAC / Linux**	**Library / Stand alone**	**Third party software - which one**	**XLS / DB / CSV / XML /CIM**
LDM-SG	IPE (Institute of Physical Energetics)	Commercial	Windows	Stand alone		XLS /DB / CSV

BASIC INFORMATION		**Software characteristics**				
Name of tool	**Developer**	**Free / Commercial**	**WIN / MAC / Linux**	**Library / Stand alone**	**Third party software - which one**	**XLS / DB / CSV / XML /CIM**
eTransport	SINTEF Energy Research	Free	Windows	Stand alone	MS Visio, AMPL and CPLEX/COIN LP Solver	XLS / DB
Samnett	SINTEF Energy Research	Commercial	Windows	Stand alone	NAG library, COIN LP solver	
Prodnett	SINTEF Energy Research	Commercial	Windows	Stand alone	CPLEX/COIN LP Solver	
OPAL/ SAMREL	SINTEF Energy Research	Comm (research)	Windows	Stand alone or extension of Samlast/Samnett and PSS/E	Matlab and Matpower or PSS/E	XLS
MODERNE	University of Strathclyde	Private use	Windows	Stand alone	Matlab	XLS
LV Planning	University of Strathclyde	Private use	Windows	Stand alone	Matlab	XLS
HMms	University of Strathclyde	Private use	Windows/Mac/Linux	Can be stand alone		
HESA	University of Strathclyde	Private use	Windows	Stand alone	Matlab	XLS
Probabilistic Load MODELLING	University of Strathclyde	Private use	Platform Independent	Library		DB / CSV
CEEMU	TECNALIA	Private use	Windows/ Linux	Stand alone	Excel	XLS
VPP	TECNALIA	Private use		Stand alone	PSS/E	
MST	TECNALIA	Private use		Stand alone		CSV
Flexibility forecasting tool	TECNALIA	Private use		Stand alone	No	DB
IPSYS	DTU	Open source	Windows/ Linux	Stand alone		CSV / XML
Flextool	VITO	Private use	Windows/ Linux	Stand alone	No	XLS/ CSV/ XML
Intelligator	VITO	Private use	Windows/ Linux	Stand alone	No	XLS/ CSV/ XML
Power Matcher	VITO	Free (open source)	Windows	Stand Alone	No	XLS/ CSV/ XML
Fi.Si. (Field Simulator)	RSE	Free (used by RSE)	Windows	Stand Alone	No	XLS/ CSV/ XML
Ma.Re.	RSE	Free (used by RSE)	Windows	Stand Alone	No	XLS/ CSV/ XML
MONET	RSE	Free (used by RSE)	Windows	Stand Alone	No	XLS/ CSV/ XML
SPREAD	RSE	Free (used by RSE)	Windows	Stand Alone	No	XLS /DB / CSV / XML
VoCANT	RSE	Free (used by RSE)	Windows	Stand Alone	Matlab	XLS/ CSV/ XML
SCUDO	RSE	Free (used by RSE)	Windows	Stand Alone	No	XLS / CSV

5 GAPS IN CAPABILITIES AND MODEL CONSOLIDATION

A survey of the tools used by the participants in the EERA JP SG for analysis of different aspects of smart grids has been carried out. The survey was carried out as a questionnaire, and 25 tools have been identified. Many of these tools are developed in house by the participants and have been developed in projects with a particular context and therefore with a focused application in mind.

The survey has shown that:

- Many of the tools are focused on simulation of distribution networks with DER units to study grid impact (mainly because the Energy management sub-programme is focused on systems with a large amount of DER units, which typically are connected in the distribution network).
- The tools include both planning and operation tools. It seems that the actual methods of analysis are varying from tool to tool since they include a variety of simulation methods grid representation and control representations.
- With the current state of the art in smart grids it is natural that many of the tools can investigate business cases.
- There are only a few analysis frameworks and more general simulation tools. The majority of the tools are more specific.
- The majority of the tools include either a business case evaluation or evaluation of the societal impact. Only very few are technology performance tools only.
- Few tools include capability to analyse cases with asymmetrical loads.
- The issues of how the DER units are being coordinated are open. Many different types of control have been implemented in the tools. This ranges from purely technical simulation tools to tools that optimize system performance based on a particular controls scheme.
- Many of the tools have not been used on large realistic cases.

There is a need for:

- Developing common cases with verified consolidated data that can be used to compare the performance of the different tools.
- Preparing common measures to compare the performance.
- Consolidation of the tools since it carries a very large overhead to maintain such a population of tools and knowledge is being lost if the results and experiences from working with the tools is preserved as e.g. improvements to the active tools or as consolidated cases.
- Further investigation on the impact of inclusion of more energy system domains.
- Further investigation with respect to the impact of physical control system and actual communication.
- Importance in dealing with the issues related to the data exchange. This huge challenge can be achieved through the compatibility with proper standards such as the Common Information Model (CIM).
- Simulation of the communication systems should be also addressed along with the possibility of the tools to perform co-simulation (which is a simulation methodology that allows individual components to be simulated by different simulation tools running simultaneously and exchanging information in a collaborative manner).
- A central challenge arises from the fact that the Smart Grids simulation brings mainly two domains together for which MODELLING and simulations tools were separated in the past: electricity and communication domains. But the interaction with other domains such as heating and gas should also be taken into consideration.

6 BIBLIOGRAPHY

[1] European SmartGrids Technology Platform, *"Vision and Strategy for Europe's Electricity Networks of the Future"*, European Commission, 2006. Available online: http://ec.europa.eu/research/energy/pdf/smartgrids_en.pdf

[2] EU Commission Task Force for Smart Grids, Expert Group 1, *"Functionalities of smart grids and smart meters"*, December 2010. Available online: http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/expert_group1.pdf

[3] Risø DTU, "Non fossil technologies in 2050 and beyond", Risø-R-1729 (EN), November 2010.

[4] European Wind Energy Association, "Powering Europe: wind energy and the electricity grid", November 2010.

[5] P. Kundur, *"Power system stability and control"*, ISBN: 0-07-035958-X, McGraw-Hill, New York, 1994.

[6] Cigrè Working Group B4.39, "*Integration of Large Scale Wind Generation using HVDC and Power Electronics*", pp. 1-157, ISBN: 978-2-85873-057-5, February 2009.

[7] European Electricity Grid Initiative*, "Mapping & Gap Analysis of Current Smart Grids European Projects"*, April 2012.

[8] SMB Smart Grid Strategic Group (SG3), *"IEC Smart Grid Standardization Roadmap"*, June 2010.

[9] NIST Smart Grid Framework 1.0, September 2009.

[10] European Wind Energy Association, *"Creating the internal energy market in Europe"*, September 2012.

[11] *"A Framework for Evaluating the Benefits and Costs of Investments in Electric Vehicle Infrastructure",* EPRI, Palo Alto, CA: 2010. Product No. 1019927.

7 ANNEX: TOOLS CHARACTERISTICS

7.1 DOC Template structure for contributions

The document template sent to the different participants is below reported in blue.

EERA Joint Programme on Smart Grids, SP2 Energy Management
Simulation tools inventory questionnaire
As part of the activities in SP2 Energy Management is collection of information on the simulation tools used by the participants to conduct studies and analyses of different smart grid solutions. This includes a range of investigations including analysis at the societal level to analysis of performance of specific control algorithms on a group of flexible consumption units.
The questionnaire consists of three parts:

1. Narrative description of the tool following the format below. Max size is 1 page
2. Table with characteristics of the tool
3. Optional free form part e.g. in the form of papers, reports that can be included as appendices

Outline for the narrative part:

Name of tool

Background

Description

Examples of use/Cases

References

7.2 XLS template

The excel table used to gather information on the tools is reported in Table 7.

Table 7 – XLS template

BASIC INFORMATION		
	Name of tool	
	Developer	
	User	
Scope of tool	Scope of the tool with respect to aim of the tool: What is the intended application of the tool, at what level is the system under study analysed: society, interaction, integration, characterization	
		TSO level
		DSO level
Primary purpose of model	Is the primary MODELLING time horizon of the tool at the operational time scale or at the planning time scale	
		Operational
		Planning
Model Context	Is the intended context to study market interaction, system wide balancing or impact on the grid	
		Market
		Balancing
		Network impact

BASIC INFORMATION		
MODELLING type	What is the MODELLING concept applied. Is it a deterministic TS model, stochastic time series, statistical with distributions as input and output	
	MODELLING approach	Deterministic
		Stochastic
		Statistical
		Time step
Economics	Is the simulation a purely technical simulation, is it calculating the impact of a particular implementation or impact at the society level	
		No economic calculation
		Business case
		Societal benefit
Energy subsystems modelled	Which subsystems of the energy systems are included in the tool	
		Electrical
		Heat
		Gas
		Other
Electric grid model	How is the electrical network modelled	
	Size of system	number of bus bars
		number of lines
		number of generators
		number of consumers
		number of controllers
	Grid MODELLING	No network model
		Regional boundary flow
		DC load flow
		Symmetrical full load flow
		Asymmetrical full load flow
	Voltage levels	number of voltage levels
Smart grid control	How is the system control modelled and at what detail	
	Control model	
		No particular control assumed, Flexible
		Particular
		Implicit, optimization
	base unit of controller	Appliance
		House
		micro grid
	Granularity of MODELLING of smart grid control	
		Individual units
		Aggregated
	Type of control	
		Direct
		indirect
		Transactional/market based
Software characteristics	General information on the software	
	Availability	Free
		Open source
		Commercial
	Platform	Windows
		Mac
		Linux
		Web based

BASIC INFORMATION		
	Type of product	
		Library
		Stand alone
		Web based
	Uses third party software	
		Which one
	Data input/output compatibility	
		Spread sheets
		Data bases
		Plain text
		XML
		CIM
Validation		
	Has the tool been validated/verified	Yes
		If Yes how
		No
References		
	References describing the tool and its application	Papers
		Reports

7.3 LDM-SG

7.3.1 Name of tool

Name: LDM-SG
Developer: Institute of Physical Energetics (IPE), Laboratory of Power System Mathematical MODELLING.
User: IPE

7.3.2 Background

LDM-SG is suitable for capital investments planning of MV and LV distribution network including local energy efficiency improvement, load management, generation in distribution facilities to help regulators, policy makers, utility managers, DS planners and engineers in decision making process.
There are four main LDM-SG functions: technical and economic estimation of the network, definition of economically appropriate actions from the given set of alternative actions (constructions, reconstruction or elimination of network elements) and terms of their realization, estimation of power supply quality and definition of the most effective actions to improve it, risk analysis as a decision-making tool under information uncertainty.

7.3.3 Description

LDM-SG is a simulation tool developed for dynamic planning of medium voltage distribution network in urban and rural areas including DER analysis. The tool allows making comparison in multi-step development up to 10 variants applying periodic regular year criteria with possibility calculating reliability and other criteria in each variant in each step.

The basic target of this tool is to investigate specific real influence of DER on distribution electric network:

- Impact on electric energy losses in distribution network
- Impact on voltage changes in distribution network
- To identify demand on capacity reserve in case of DG outage
- The optimal electrical network structure tailoring required for the transmission of electricity surplus generated by independent power plants

Optimal technical requirements have been elaborated for connection of independent power plants to electrical networks of different capacities, operation modes and power plants equipped with automatics thus optimizing electrical network configuration. LDM-SG can be used to meet distribution system requirements intensified by SGT improvements, improved technical capability in the areas of interconnection and control, as well as regulatory attention on the potential benefits of DER.

7.3.4 Examples of use/Cases

LDM-SG has been used for situation simulation the real objects of Latvian western electric network. Four objects have been selected and analysed:

- Three HPPs (Hydro Power Plants) connected to the 20 kV network (Aizputes HPPs);
- Four HPPs connected to the 20 kV network (Saldus HPPs);
- Two co-generation electric power plants and two wind power plants connected to the 110 kV network (Grobinas substation);
- 33 wind generators connected to the 20 kV network (Wind farm).

7.3.5 References

[12] Krishans Z., Mutule A., Merkuryev, Y., & Oleinikova, I. (2011). Dynamic Management of Sustainable Development: Methods for Large Technical Systems. Berlin: Springer. DOI: 10.1007/978-0-85729-062-5_10.

[13] Krishans Z., Mutule A., Kutjuns A. Integration of distributed generation in the networks of Latvian power system. PowerTech 2005, Russia, S. Petersburg.

7.4 eTrasnport

7.4.1 Name of tool

Name: eTransport
Developer: SINTEF Energy Research
User: External user under license

7.4.2 Background

New emerging technologies yield better possibilities to design sustainable energy systems for the future, but also introduce more complex energy systems to design, operate and maintain. Strategic planners in modern multi-energy companies need to consider complementarities between electricity, heat and gas within their own company, and public planners need to give a fair and neutral evaluation of projects across the traditional energy supply systems.

Furthermore, it is becoming more and more important to show that a company has a broad system perspective in planning and operation, where choices between multiple infrastructures have to be made subject to environmental, geographic and economic constraints. Complex analyses and decisions have to be documented in a formal and transparent way, also for opinion groups without technological background.

To meet this development, more comprehensive and flexible planning tools are needed, in particular at distribution system level. SINTEF Energy Research has developed a PC based optimization model for planning of local energy systems where different energy carriers and technologies are considered simultaneously. The model gives the user a graphical overview of a given energy system (e.g. municipality, city, suburb) with respect to costs, environmental consequences and use of local energy resources. The current version can optimize the construction of infrastructure for most relevant energy carriers; electricity, district heating, cooling, gas, waste and biomass, including conversions between these. It is not limited to continuous transport like lines, cables and pipes, but can also include discrete transport by ship, road or rail.

Since 2001 the model development has been funded by the Research Council of Norway and 11 Norwegian energy companies.

7.4.3 Description

The main task of the eTransport model is to optimize investments in infrastructure over a planning horizon of several decades to bring available energy to the end user in such quantities and in such form that the end users demands are covered in the economically and environmentally best way possible. As part of the investment analysis, however, the model also optimizes diurnal operation for different periods of the year for each alternative system design. This operational module can be run independently from the investment module. Mathematically, the model uses a combination of Linear Programming (LP), Mixed Integer Programming (MIP) and Dynamic Programming (DP).

A Windows-based graphical user interface is developed where the user can design the energy system model by dragging modules from a component library and dropping them in the drawing area. All data input and adjustments are made in this interface, and the user can run simulations and examine the results without having to edit complex code or data files. The complete model is stored in a database and results can be exported to MS Excel.

7.4.4 Examples of use/Cases

During development the model has been tested on a number of different case studies among the project participants. The case studies have enabled analyses of new challenges related to energy efficiency and environmental consequences, and has demonstrated how decisions regarding one energy technology/carrier may influence other energy carriers in the same area:

- Waste fuelled CHP with municipal District Heating (DH) network
- Gas fired CHP with DH network vs. electricity expansion in suburb
- Operation of large multi-fuel DH network
- Municipal energy plan
- Municipal DH network with biomass
- Large scale energy transport by gas pipelines, LNG ships or HVDC transmission
- Gas and DH as alternative energy services in city
- Expansion of municipal DH network with heat pumps and oil/gas boilers
- Large scale infrastructures of gas, electricity and CO_2
- Gas, heat pumps and DH as alternative energy services to residential areas
- Corporate profitability vs. socio-economic optimization in DH network
- MODELLING of cooling and low temperature distribution
- Multivariable models for storage and transport of biomass
- Biogas and heat pumps in residential area
- Biogas and cogeneration from slaughterhouse
- Low temperature distribution in residential area
- LCA in local energy system studies
- Energy chains for biofuel production
- Low temperature heat, gas and cooling in municipality

Many of these case studies are performed as master theses at The Norwegian University of Science and Technology (NTNU). Several of them are documented in Norwegian only.

7.4.5 References

[14] B H Bakken: *Planning of Distributed Energy Systems with Parallel Infrastructures: A Case study* in T.J. Hammonds (ed), Renewable Energy, ISBN 978-953-7619-52-7.

[15] S van Dyken, B H Bakken, H I Skjelbred: *Linear mixed integer models for biomass supply chains with transport, storage and processing,* Energy 35 (2010) pp 1338-1350.

[16] B H Bakken and I von Streng Velken: *Linear Models for Optimization of Infrastructure for CO2 Capture and Storage*, IEEE Transactions on Energy Conversion, VOL. 23, NO. 3, sep 2008.

[17] B H Bakken, H I Skjelbred, O Wolfgang: *eTransport: Investment Planning in Energy Supply Systems with Multiple Energy Carriers*, Energy 32 (2007), pp 1676-1689.

[18] B H Bakken, A T Holen: *Energy Service Systems: Integrated Planning Case Studies,* Proc. IEEE PES General Meeting 2004, Denver, CO, June 2004.

7.5 Prodnett

7.5.1 Name of tool

Name: Prodnett
Developer: SINTEF Energy Research
User: SINTEF, Research prototype

7.5.2 Background

Prodnett has been developed within the research project "Power System Analyses and Transmission Planning in a Changing Environment". This project has also funded the development and testing of several other models with different scopes and features.

The Prodnett prototype was constructed based on the experience from the hydro power scheduling model ProdRisk. In ProdRisk, the SDDP-algorithm (Stochastic Dual Dynamic Programming) is applied to the detailed hydro-thermal system in a regional or local system, where the price can be a stochastic exogenous input. Prodnett extends ProdRisk by introducing the possibility to model power flow constraints, start-up costs on thermal units and wind power.

7.5.3 Description

Prodnett is an SDDP-based network-constrained market model. The model has a detailed description of hydropower and allows the modelling of power flow constraints using a detailed transmission network description. In addition, the model also handles start-up costs on thermal units and the use of wind power time series. Prodnett is suited for medium- and long-term hydro-thermal power scheduling with a minimum time step of one hour.

7.5.4 Examples of use/Cases

Prodnett has been tested on two different cases. Initial testing was performed on an 4-area test system established at SINTEF Energy Research.

Later on, Prodnett was tested on a realistic representation of the Icelandic power system provided by Landsvirkjun. In this case study Prodnett was tested with sequential time-resolution and with stochastic exogenous price. As these simulations were computationally demanding, parallel processing functionality was applied. Iceland's power generation is primarily based on hydropower, which makes the system well suited for balancing possible future introduction of wind power plants and export to the UK power market. In general, the results indicated that when using a finer time resolution, and thus adding more constraints to the system, the simulations become more realistic. In particular, the limited transmission capacity between the major watercourses complicates the computation of the total balancing potential on Iceland. Simulations without power flow constraints clearly overestimated the capability of exporting power to the UK market and gave unrealistic reservoir operation.

7.5.5 References

[19] A Helseth, A Gjelsvik, B Mo, and G Warland: *Prodnett – a market model based on SDDP including power flow constraints*. Technical Report TR A7165, SINTEF Energy Research, 2011.

[20] A Helseth, A Gjeslvik, B Mo, and U Linnet: *A model for optimal scheduling of hydro-thermal systems including wind power: Application to the Icelandic case*. Submitted to IEEE Transactions on Sustainable Energy.

7.6 Samnett

7.6.1 Name of tool

Name: Samnett
Developer: SINTEF Energy Research
User: SINTEF, External users under licence, TSOs, Producers

7.6.2 Background

Samnett has been developed within the research project "Power System Analyses and Transmission Planning in a Changing Environment". The primary goal of the Samnett activity was to establish a model comparative to the Samlast model ("EPF model"), but with a more optimal treatment of transmission system bottlenecks.

7.6.3 Description

Congestion management in the Nordic power system is mainly by use of market splitting (price areas). As a consequence, congestion of main bottlenecks in the Nordic system leads to price differences between price areas. The prices at each node within a price area will be the same, as opposed to the case with nodal prices where prices within an area differ because of congestion and marginal losses.

In the Nordic power market, the EFI's Multi-area Power Market Simulator (EMPS) model is in widespread use for general system analyses as well as price forecasting and generation scheduling [21], [22], [23], [24]. The EMPS model is a fundamental model for simulation of an optimal schedule, with optimization based on a heuristics-assisted stochastic dynamic programming algorithm for hydrothermal scheduling. The model has a minimum time resolution of 1 hour and has recently been extended to allow MODELLING of detailed wind power and start-up costs on thermal generators.

In its original version, the EMPS model limits the flow between connected price areas through maximum transfer capacity limits on the corresponding interconnections. To improve the network representation in the EMPS model, additional functionality has been developed coupling results from the market model to a transmission network model. In turn, sensitivity signals from power flow studies on the transmission network are fed back to the market model to adjust production schedules so that overloads are alleviated.

The extended model finds the optimal utilization of the transmission network in power markets relying on area pricing. It combines detailed hydropower scheduling and transmission network analyses adapted to the price-area model used in the Nordic power market. Furthermore, it is well suited for analyses of upcoming challenges to the European transmission network, such as the possible integration of large-scale offshore wind power and the increased utilization of hydropower for balancing purposes.

7.6.4 Examples of use/Cases

Samnett has been tested extensively, both on a 4-area test system established at SINTEF Energy Research and on full-scale data sets provided by Nordic TSO's Statnett and Fingrid.

7.6.5 References

[21] A Helseth, G Warland, B Mo, and O B Fosso: *A hydrothermal market model for simulation of area prices including detailed network analyses*. European Transactions on Electrical Power, Article first published online: 24 JUL 2012.

[22] A Helseth, G Warland, B Mo, and O B Fosso: *Implementing network constraints in the EMPS model*. Technical Report TRA6891, SINTEF Energy Research, 2010.

[23] A Helseth, G Warland, B Mo, and O B Fosso: *Samnett – the EMPS model with power flow constraints*. Technical report, SINTEF Energy Research, 2011.

[24] K. S. Hornnes: *A model for coordinated utilization of production and transmission facilities in a power system dominated by hydropower*. PhD thesis, Norges Tekniske Høgskole, 1995.

7.7 OPAL-SAMREL

7.7.1 Name of tool

Name: OPAL-SAMREL
Developer: SINTEF Energy Research
User: SINTEF, Research Prototype

7.7.2 Background

The OPAL methodology for reliability analysis is based on an analytical contingency enumeration approach. OPAL is primarily applicable for long-term planning purposes comprising the power generation and transmission system. The methodology is documented in detail in a requirement specification [25] and it is implemented in a prototype tool in Matlab and Excel [26].

7.7.3 Description

OPAL is a methodology for reliability analysis in meshed power networks. OPAL takes into account protection system faults and time-variation in interruption costs. The reliability methodology developed consists of seven main stages:

1. Definition of analysis
2. Generation of contingency lists
3. Consequence analysis
4. Reliability assessment
5. Inclusion of protection system faults
6. Calculation of time-dependent variation and correlation between parameters
7. Calculation of reliability indices

7.7.4 Examples of use/Cases

OPAL has been tested on variants of the IEEE Reliability Test System (RTS) and the Roy Billinton Test System (RBTS), in addition to several regional and national case-studies based on the Norwegian power system.

7.7.5 References

[25] K Samdal, G H Kjølle, O Gjerde, J Heggset, A T Holen: *Requirement specification for reliability analysis in meshed power networks*, SINTEF Energy Research, Technical report, TR A6429, 2006.

[26] M Korpås: *OPAL prototype implementation in Matlab and Excel*, SINTEF Energy Research, Memo, AN 08.12.139, 2008.

[27] G Kjølle, K Samdal, J Heggset, O Gjerde: *The OPAL methodology for reliability analysis in meshed power networks*. SINTEF Energy Research, Memo, AN 08.12.140, 2009.

[28] O Gjerde, G Kjølle, L Warland, M Korpås, G Warland: Integration of market and network models for security of electricity supply analysis, SINTEF Energy Research, Technical report, TR A6751, 2009.

7.8 CEEMU

7.8.1 Nameplate of tool

Name: CEEMU
Developer: TECNALIA
User: TECNALIA

7.8.2 Background

CEEMU was developed to facilitate the analysis of the economic feasibility of the development of MicroGrids. The objective of the tool is to perform a Net Present Value (NPV) analysis of the installation of a MicroGrid, but taking into account that the equipment installed will provide electricity to the customers of the MicroGrid, as well as, heat at the same time. This tool analyzes the economic return of installing different types of microgeneration devices (renewable and non-renewable sources).

7.8.3 Description

CEEMU is a simulation tool developed to perform economic analysis of MicroGrids composed of different types of microgenerators, able to provide electrical and thermal energy to the end users. It is a planning tool and as such, it considers a complete year of operation to take into account the data for performing the analysis. It is very flexible in the sense that different types of components (CHP, PV, Wind, Geothermal) can be included into the model.
CEEMU calculates the cash flows corresponding to each of the components, as well as, the investment costs and different rates of return can be simulated. The tool does not require the exact consumption profiles of every customer but from an average consumption, it is able to make the estimation of the hourly consumption. Similar techniques are used to compute the production of renewable resources

7.8.4 Examples of use/Cases

CEEMU has been used to design the thermal and electrical MicroGirds that have been built in a neighbourhood within the city of Vitoria-Gasteiz, which is located in the Basque Country.

7.8.5 References

[29] T Ander Romero, Eneritz Barreiro, Eugenio Perea: *Sustainable Urban Planning in Toledo: A case of study through a holistic energy approach* in proc 45th ISOCARP Congress , Porto, Portugal, October 2009.

7.9 Validation of VPP D-1 Schedule

7.9.1 Nameplate of tool

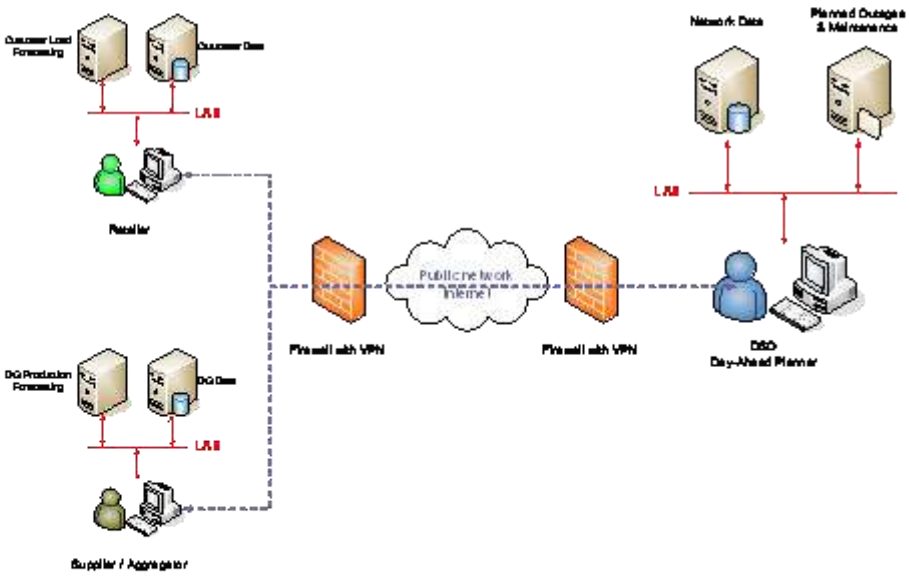
Name: Validation of VPP D-1 Schedule
Developer: TECNALIA
User: TECNALIA

7.9.2 Background

The application for the Validation of VPP D-1 Schedule is developed for day ahead planning where demand profiles, generation profiles and maintenance operations are applied to create a network model, execute a load flow and identify possible network constraints and request corrective actions.

7.9.3 Description

The Validation of VPP D-1 Schedule tool is based on a set of Python scripts for automation, MS Excel files as data repository and PSS/E for power system simulation.



The electricity retailer calculates and submits the power demand profiles for the next day; the supplier for the distributed generators of the considered are forecasts and submits the power generation profiles for the same time period. The distribution system operator applies those profiles to the network model and calculates a power flow determining possible overloaded transformers and/or circuits and out of limit voltages.

The same scheme and a fairly similar procedure may be applied to study planned outages, changes on the demand profile due to demand response actions, re-dispatches of generation units for the provision of ancillary services, etc.

7.9.4 Examples of use/Cases

Validation of VPP D-1 Schedule has been applied to validate Electrical Vehicle aggregator profiles, reject those resulting on network constraints and finally assess the re-dispatch feasibility.

7.9.5 References

FENIX (EC FP6 No. SES6 – 518272), http://www.fenix-project.org/

7.10 MST (Microgrid Simulation Tool)

7.10.1 Nameplate of tool

Name: MST (Microgrid Simulation Tool)
Developer: TECNALIA
User: TECNALIA

7.10.2 Background

MST was created as a software tool for simulating the physical devices which are monitored and/or controlled in a Microgrid. The objective is to be able to test in a simulation environment Microgrid control software prior to its deployment in a real Microgrid. The simulation software addresses mainly two aspects

to be simulated: 1) Communication protocols used by equipment and 2) steady state electrical behaviour of Microgrid components.

7.10.3 Description

A Microgrid consists of a set of generation devices, storage systems, loads and all the needed equipment to distribute electricity (lines, protections, etc) and control the different devices. A Microgrid can operate either connected to the main grid or islanded from it depending of the operating conditions. Being a Microgrid a small electricity system, it needs a high level control system in charge of taking the decisions about how much power needs to be generated and consumed, what generating unit is going to produce electricity, how much electricity is going to be exported or imported form the main grid etc. A control system taking such operating decisions needs to communicate with the different controllable devices (generators, loads, measuring devices etc.).

The Microgrid Simulation Tool allows testing different control systems including control algorithms and communications implementation before deploying the control system in a real Microgrid. The features currently implemented include:

- Controllable generators: Active Power set point, Start/Stop, Current/Voltage source operating modes, droop control characteristics etc.
- Non Controllable generators: Active and reactive power monitoring
- Loads: ON/OFF switching
- Measuring devices: Active power, reactive power, frequency and voltage monitoring
- Microgrid level: Simulation of power exported and imported form the main grid. Simulation of frequency variations when operating in islanded mode

The simulation of communications is being done taking as basis the real devices present at Tecnalia’s laboratory. These include Modbus RTU, Modbus TCP and some proprietary protocols. The SW tool allows to easily implementing new protocols in order to adapt the tool to devices from different vendors.

7.10.4 Examples of use/Cases

MST has been used to develop and test control systems for Microgrids. In particular a Microgrid Management System has been developed by Tecnalia. This MEMS system allows operating a Microgrid both in grid connected mode and islanded modes in the most economical way for the Microgrid users.

The MEMS system was tested in the MST environment and the deployed in the Microgrid laboratory of Tecnalia.

7.10.5 References

[30] Joseba Jimeno, Jon Anduaga, Jose Oyarzabal and Asier Gil de Muro: *Architecture of a microgrid energy management system* European Transactions on Electrical Power 2011; 21:1142–1158, April 2011, DOI: 10.1002/etep.443

7.11 Flexibility Forecasting tool

7.11.1 Nameplate of tool

Name: Flexibility Forecasting tool
Developer: TECNALIA
User: TECNALIA

7.11.2 Background

This tool was developed to calculate the demand response of residential customers to incentives sent by the aggregator to either increase or decrease its consumption. The objective of the tool is to perform a simulation of the aggregated response of several residential users to different incentives.

7.11.3 Description

This is a simulation tool developed that takes into account the models of appliances used by households and adds to the models penalizations for comfort losses. The models that have been currently implemented correspond to HVAC and shiftable devices, such as, washing machines. The tool considers the demand response operation during a certain period of the day and knowledge of the day ahead prices of electricity, base consumption of the group of customers and the incentives offered are used as input to compute the response of the user.

The tool employs a bottom-up approach based on physical end-use load models where the reply of individual customers is calculated by modifying the operating parameters according to the incentive signals and considering its probability of use of the different devices. Simulation of the individual responses is carried out with an optimization algorithm that minimizes the electricity bill whilst maintaining consumer's desired comfort level. Once the response of each individual residential customer is calculated, the results are aggregated and returned as a result of the execution of the tool.

7.11.4 Examples of use/Cases

The tool has been used for calculating the sensitivity to prices within the ADDRESS project and it will be used within the demonstration test sites that are going to take place in Castellon (Spain) and the Brittanny Region (France).

7.11.5 References

[31] C. Gorria, M. Lezaun, J.Jimeno, I. Laresgoiti and N. Ruiz: Gesti´on, optimizaci´on y estimaci´on del consumo el´ectrico dom´estico condicionado por la oferta de incentivos in proc of the RSME conference on transfer and industrial mathematics, Santiago de Compostela, Spain, July 2011.

[32] M. Lezaun Iturralde, C. Gorria Corres, J. Jimeno Huarte, I. Laresgoiti Rementeria, N. Ruiz Carames: *Gestión óptima del consumo eléctrico mediante una política de inventivos,* XXXIII Congreso Nacional de Estadística e Investigación Operativa, Madrid, Spain, April 2012.

7.12 IPSYS

7.12.1 Nameplate of tool

Name: IPSYS
Developer: DTU
User: DTU (will be open sourced)

7.12.2 Background

IPSYS was developed to fit in the gap between traditional planning tools which are using timesteps in the hour range and transient/dynamic models used to do stability analysis. The objective of IPSYS has been to provide a tool that can be used to study controllers at the supervisory control level in order to investigate the impact of various control strategies and the impact on the network.

7.12.3 Description

IPSYS is a simulation tool developed for the simulation of systems with different sources of renewable energy. It is very flexible with respect to system configuration and can easily be extended with new components. It has an explicit MODELLING of the electric grid implementing a full symmetrical load flow and it can simulate systems with other domains such as district heating water supply and fresh water. It has further been extended with the ability to include systems with hydro and gas (e.g. hydrogen) sub-systems. This enables the analysis of systems with more than one stream of products (electricity, water, heat etc.) taking the interdependencies that arise through couplings in the components (e.g. power and waste heat from a diesel genset) into account.

Another of IPSYS' strong points is its capability to explicitly simulate the supervisory controller of the system. The supervisory controller model scheme is based on a sensor/actuator model of the units that are being controlled. This means that the components of the system participating in the control of the system have sensors that provide input to the controller and actuators controlling the behaviour of the components that can be accessed through signals issued by the supervisory controller. This allows for the programming of supervisory controllers that are very close to physical implementation. IPSYS also allows a hierarchy of controllers, i.e. controllers that are controlled by controllers using the same interaction model of sensors and actuators.

7.12.4 Examples of use/Cases

IPSYS has been used for investigating the operation of the power system of the Faroe Islands. The power system consists of a mix of diesel, hydro and wind generation. IPSYS was used to simulate the present situation of the system (at that time) and to investigate how increased levels of wind power would impact the system performance if the operating strategy was not changed, but different changes were made to the generation portfolio.

7.12.5 References

[33] Bindner H, Gehrke O, Cronin T: *IPSYS – a tool for development and analysis of supervisory controllers for hybrid systems* in proc 6th European Conference on PV-Hybrids and Mini-grids, Chambery, France, April 2012

7.13 Flextool

7.13.1 Nameplate of tool

Name: FlexTool
Developer: VITO
User: VITO

7.13.2 Background

The FlexTool was developed to cover the gap between the 'demand supply matching tools' that focus on the technical possibilities of flexibility, and the 'market tools' that focus on trading of traditional generation capacity. The goal of FlexTool is to estimate the value of the flexibility of a cluster of devices in a certain business case.

7.13.3 Description

FlexTool allows the MODELLING of flexibility through a FlexGraph, a graphical representation of flexibility with the energy consumed on the y-axis and the time on the x-axis. In this plane two lines are plotted; a minimum energy consumption and a maximum energy consumption. The area between these two lines is a measure for the available flexibility. Also it is possible to add up different FlexGraphs, which allows for clustering of flexibility. Traditionally it's is extremely difficult to calculate all the different options with which to control a cluster of flexible devices, due to the 'curse of dimensionality' (every time step increases the amount of control options for a cluster of devices exponentially, making an optimal path extremely difficult to calculate). At the cost of accuracy it becomes possible to do a good estimate of the value of flexibility using FlexTool.
Behind the FlexTool there is a library of models, called 'Modelllib', which contains a collection of lab validated models. These models can then be added to a cluster, of which the FlexGraph can be calculated. This FlexGraph is the input for the economic analysis. A number of default business cases are available in the program, like peak shaving and day ahead trading, time of use tariffs, etc. The outcome of the calculation is an estimate of the value of the flexibility.

7.13.4 Examples of use/Cases

The FlexTool has been applied in a number of cases as a quick estimate of a potential business case. Examples are:

- An industrial virtual power plant, where the business case is contract optimization.
- The estimate of the value of household Flexibility in a time of use tariff setting.
- An industrial wind balancing case.

7.14 Intelligator

7.14.1 Nameplate of tool

Name: Intelligator
Developer: VITO
User: VITO

7.14.2 Background

The IntelliGator was developed to control large clusters of flexible appliances. These flexible appliances can be household appliances, but also industrial installations, or building management systems for office buildings. This coordination mechanism can be applied, not only to different appliances, but for different business cases; from contract optimization to day ahead market trading, or capacity constraints in the electricity grid.

7.14.3 Description

IntelliGator is an event based market-based coordination mechanism, which allows it to respond instantaneously to changes in a cluster of flexible appliances. It utilizes software agents connected to individual appliances to gather flexibility, which is traded through a hierarchical structure of virtual markets. Through this hierarchical structure the scalability of this system is enormous, allowing the simultaneous control of millions of appliances.
Market-based control algorithms have a strong emergent behaviour within them, which means that; without any specific scheduling code on higher levels it seems as if there is some sort of scheduling or planning going on within the cluster. This automatic scheduling works on time spans of up to half a day. For the integration of prediction and scheduling IntelliGator+ was developed. This is a suite of optimizations algorithms that greatly enhances the scheduling capabilities for a cluster of devices through the use of a suite of algorithms, specific for different settings.

7.14.4 Examples of use/Cases

The IntelliGator has been applied in a number of cases. Examples are:

- An industrial virtual power plant, where the business case is contract optimization.
- The optimization of household Flexibility in a time of use tariff setting.
- The optimization of the flexibility of a parking full of electric vehicles.

7.14.5 References

[34] A scalable three-step approach for demand side management of plug-in hybrid vehicles Stijn Vandael, Member, IEEE, Bert Claessens, Member, IEEE, Maarten Hommelberg, Member, IEEE, Tom Holvoet, Member, IEEE, and Geert Deconinck, Senior Member, IEEE, IEEE Transactions on smart grids, in press

7.15 Powermatcher

7.15.1 Nameplate of tool

Name: PowerMatcher Simulation Tool & Public Agents Library
Developer: TNO
User: TNO (open source)

7.15.2 Background

PowerMatcher technology is a distributed energy system architecture and communication protocol, which facilitates implementation of standardized, scalable Smart Grids, which can include both conventional and renewable energy sources. PowerMatcher Technology optimizes the potential for aggregated individual electricity producing and consuming devices to adjust their operation in order to increase the overall match between electricity production and consumption, through dynamic, real time pricing. These real time prices provide incentives for off-peak electricity usage and on-peak electricity generation, improving the load factor of the grid.

7.15.3 Description

The PowerMatcher Simulation Tool is made for simple demonstrations of the PowerMatcher technology. Although it can show graphs, it is not meant as an analysing tool. For doing large scale analysing, the tool is able to retrieve data from the Agents that they make public and write these data to disk (csv file).
A number of devices are included in the public agents library. Most of which have been validated with real data from existing field tests (e.g. PowerMatching City in Hoogkerk, NL). Devices in the public agents library are typically programmed with two types of controllers, business as usual non market based control and PowerMatcher control. In this way simulations can be run with a reference case as well as PowerMatcher case. All devices can be configured via the simulation tool or via a pmst (xml based) file. Further simulations can be run in real time or virtual faster speeds. Examples of devices are; heat pumps, micro CHPs, wind turbine, photovoltaic, base household load etc.

7.15.4 Examples of use/Cases

The PowerMatcher simulation tool and associate public agents library has been used to investigate a number of different scenarios. Namely, the impact of the technology in specific applications: congestion management in distribution grids using smart-charging electrical vehicles, efficient integration of wind power and peak-load avoidance in extreme circumstances.

7.15.5 References

[35] Koen Kok et al, *Dynamic Pricing by Scalable Energy Management Systems - Field Experiences and Simulation Results using PowerMatcher, from* IEEE PES General Meeting., July 2012

[36] *D 6.2 Estimation of Innovative Operational Processes and Grid Management for the Integration of EV* from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement No. 241295., June 2011

7.16 Fi.Si. Field Simulator

7.16.1 Nameplate of tool

Name: FiSi (Field Simulator)
Developer: RSE
User: RSE

7.16.2 Background

FiSi (Field Simulator) was developed to assess the behaviour of optimization & control algorithm for active distribution networks.
The objective of FiSi is to replicate the behaviour of the system (network+generators+loads+storages), exchanging ‘measurements’ and ‘setpoints’ with the controller to verify its performances.

7.16.3 Description

FiSi is based on load flow calculations; it provides ‘measurements’ (that is voltage at nodes, current in branches s and active/reactive power information) regarding the elements of the system. It is able to accept ‘setpoints’ from the controller (for example modulation of active power for a generator). In addition, it allows to insert ‘events’ (disconnection or sudden drop of generated power) to verify the proper reaction of the controller.

7.16.4 Examples of use/Cases

FiSi was tested on both MV and LV test networks, representing real and simplified cases, to test different centralised control algorithm. Inclusion of generators with local controllers is under development.

7.16.5 References

Reports on RSE website (in Italian).

7.17 Ma. Re.

7.17.1 Nameplate of tool

Name: Ma. Re. (Margine Rete = network margin)
Developer: RSE
User: RSE

7.17.2 Background

Spreading of Electric Vehicles may involve several criticalities for distribution networks; Ma.Re. was developed to evaluate different recharge models (slow, fast, direct/smart) or real MV and LV networks, both in the planning and in the operation phase.

7.17.3 Description

Ma.Re allows to evaluate the margin to allow recharge of Electric Vehicles on real LV (slow charge) and MV (fast charge) networks and to identify possible grid improvements.

7.17.4 Examples of use/Cases

Ma.Re. was tested on the real MV/LV network of Milan, getting data from the automated metering infrastructure.

7.17.5 References

G. Mauri, E. Fasciolo, et al., "The impact of EV's recharging on the planning of a typical Italian urban area" Cigrè International Symposium, 2011, Bologna,

Reports on RSE website (in Italian).

7.18 MONET

7.18.1 Nameplate of tool

Name: MONET
Developer: RSE
User: RSE

7.18.2 Background

MONET was developed to analyse the demand and the generation on a regional basis, taking into account the interconnections within the sub-areas, to obtain a detailed model of the energy system.

7.18.3 Description

MONET is a multiregional model of the Italian energy system. The main feature of the model is the multiregional structure through which the energy system of each Italian region is described and solved within a single decision problem and according to one objective, which usually is represented by the minimization of the overall system cost. Compared to the case of a single region model, the multiregional model MONET allows a specific description of the different regional characteristics in terms of technologies, demands, potential, availability of resources and interconnections with neighboring systems, assigning to each regional system specific characteristics that belong to him.
The model MONET inherits the description of the Italian power system from the previous experience of the model MATISSE updating and improving it both as regards the supply side as the demand one.

MONET main characteristic is represented by its multi-regional approach (different from usual models): it allows to describe and to solve the energy system of each region within the whole national problem, minimizing the global cost. Compared to a national single model, the multi-regional approach permits a detailed description of specific regional characteristics in terms of technologies, demand, RES potential, interconnections with adjacent regions.

7.18.4 Examples of use/Cases

MONET was used in the burden sharing procedure, to quantify the intermediate and final goals that each province and autonomous region has to achieve in order to get the national ’20-20-20’ targets for the overall share of RES in gross final consumption of energy.

7.18.5 References

Ministry of Economic Development, Decree 15 march 2012, “Definizione e qualificazione degli obiettivi regionali in materia di fonti rinnovabili e definizione della modalita' di gestione dei casi di mancato raggiungimento degli obiettivi da parte delle regioni e delle provincie autonome (c.d. Burden Sharing).” [Definition and Characterization of the regional targets on renewable sources, and definition of managing procedures on cases of failed achievement of the goals by the regions and autonomous provinces] – burden sharing.

Reports on RSE website (in Italian).

7.19 SCUDO

7.19.1 Nameplate of tool

Name: SCUDO7 (Simulazione del Carico elettrico di Utenze DOmestiche, simulator of electric loads for residential customers)
Developer: RSE
User: RSE

7.19.2 Background

SCUDO7 (Field Simulator) was developed to build a statistical model of the residential curve and to assess both the contribution of each appliance to the overall load curve and the effects / benefits of moving its usage in different periods of the day.

7.19.3 Description

SCUDO 7 allows building a detailed model of the residential dwelling, by accurately describing the characteristics of each domestic appliance; it is based on MonteCarlo simulation and its output is the decomposition of the residential load curve into the different contributions of each appliance.

7.19.4 Examples of use/Cases

SCUDO7 has been tested using the data coming from a panel, made of 1000 families who are statistically representative of the whole Italian household population, and about which the following data are available:

- consumption data measured by smart meters every 15 minutes;
- information about the electric appliances each family owns and about their usage on the different days of the week and at different time of the day, gathered by a set of periodic computer assisted interviews.

The goal is to assess the impact of the introduction of the mandatory ToU tariff among the Italian residential customers e analyze how their habits have been affected by such a change.

7.19.5 References

Reports on RSE website (in Italian).

7.20 SPREAD

7.20.1 Nameplate of tool

Name: SPREAD
Developer: RSE
User: RSE

7.20.2 Background

Efficient planning tools for distribution networks should enable maximal utilization of existing capacities, i.e. finding a way to work around operational limitations, which is one of the most important features of active distribution networks with significant amount of distributed generation installed. SPREAD is a network planning methodology based on the principle of dynamic programming.

7.20.3 Description

SPREAD allows the optimal planning of MV distribution networks with DG, taking into account expansion over time and usual technical constraints. The heuristic optimization algorithm minimizes the generalized cost of the network constituted by the CAPEX (investments for new lines, the revamping of existing lines and primary substations, and network automation) and the OPEX (e. g. losses and maintenance).

One of the most important feature of SPREAD is that the planning actions available to solve network problems like poor voltage regulation or excessive power flows are not only based on the building of new lines or on network topology modifications, but also on the application of the control actions typical of active networks.

7.20.4 Examples of use/Cases

SPREAD was verified on different MV test networks, representing both simplified and real cases. It is used in combination with Ma.Re. §7.17 to locate possible EV recharge stations connected to the MV grid.

7.20.5 References

[37] G. Celli, R. Cicoria et al.,“Multi-Year Optimal Planning Of Active Distribution Networks”, CIRED 2007.

[38] G. Celli, R. Cicoria et al, “Comparison Of Planning Alternatives for Active Distribution Networks”, CIRED Workshop 2012.

Reports on RSE website (in Italian).

7.21 VoCANT

7.21.1 Nameplate of tool

Name: VoCANT (Voltage Controller for Active Networks)
Developer: RSE
User: RSE

7.21.2 Background

VoCANT is based on an optimization procedure to minimize costs of control strategies needed to satisfy technical constraints.
The goal of the procedure is to identify an admissible condition for a MV network in presence of DG, with the minimum dispatching cost for the DSO. The algorithm can consider different ‘business models’ regarding the rewards for ancillary services provided by DERs, ranking the available regulation resources in a given order.

7.21.3 Description

The algorithm developed by RSE focuses on increasing the hosting capacity of the network by means of Voltage control of Medium Voltage (MV) feeders, even in presence of storage units operated by the DSO.
To maintain all parameters within desired ranges it relies on different resources, both “internal” and “external”, of increasing cost: On Load Tap Changer (OLTC), Reactive power injection/absorption from controllable resources (sub-set of DERs); Active power from controllable resources (sub-set of DERs); Storage unit(s), directly operated by the DSO. The algorithm is able to manage overall constraints regarding the HV-MV exchange, in terms of reverse power flow or reactive power.

7.21.4 Examples of use/Cases

VoCANT was tested on MV test networks, representing real and simplified cases of Italian networks.
Real field testing on the MV network of a large city in Italy has started in 2012; the integration phase within the existing SCADA is completed, the testing on a ~160 node network will be completed in 2013.

7.21.5 References

[39] D. Moneta, A. Gelmini, C. Carlini, M. Belotti, “Storage units: possible improvements for voltage control of MV distribution networks”, 17th PSCC.

[40] C. Carlini, S. Ceotto et al., “Innovative control method for active distribution networks in an uncertain scenario”, EVER 2013, March 2013, Monaco http://conference.evermonaco.com/index.php

[41] Reports on RSE website (in Italian).

Table 8 – Tool comparative table (part 1)

BASIC INFORMATION			SCOPE OF TOOL	PRIMARY PORPUSE OF MODEL	MODEL CONTEXT	MODELLING TYPE		ECONOMICS	ENERGY SUB SYSTEM MODELLED	ELECTRIC GRID MODEL			
			What level of voltage the system is studied (DSO/TSO)	Is the primary MODELLING time horizon of the tool	context: market interaction, system balancing or network impact	What is the MODELLING concept applied. Is it a deterministic TS model, stochastic time series, statistical with distributions as input and output		Is the simulation a purely technical simulation, is it calculating the impact of a particular implementation or impact at the society level	Which subsystems of the energy systems are included in the tool	How is the electrical network modelled			
										Size of system	Grid MODELLING	AC Load flow	Voltage levels
Name of tool	**Developer**	**User**	**TSO/DSO level**	**Operational /Planning**	**Market/ Balancing /Network impact**	**Deterministic/ Stochastic / Statistical**	**Time Step**	**No economic calculation /Business case/ social benefit**	**Electrical / heat / gas/ other**	**Max number of BUS LINES/GENERATORS / CONSUMERS/ CONTROLLERS**	**No network model /DC load flow**	**Symmetrical/ asymmetrical load flow**	**number of voltage levels**
LDM-SG	IPE (Institute of Physical Energetics)	IPE	DSO	Planning	Network impact	Deterministic / Statistical	1-5 year, (regime calc.- 1 month)	Business case / Social benefits	Electrical	600 / 1000 / 300 / 600		Symmetrical load flow	5
eTransport	SINTEF Energy Research	Research prototype with license for external use	Both	Both	Market / Network impact	LP in operational module, DP in investment module an SDP versions is prototype	Time step 1 hour in operational module, years in investment module	The model calculates the least cost development plan for a given area/region	Electrical / heat / gas / cooling and biomass	Limited by computer capacity	DC LF		No specific limitation
Samnett	SINTEF Energy Research	TSOs, Producers	TSO	Planning	Market / Network impact	Stochastic		Fundamental economic model which aims at maximizing socio-economic surplus.	Only the electric power system is explicitly modelled.	Limited by computer capacity (tested on 3000 bus bars system)	DC LF		
Prodnett	SINTEF Energy Research	Research prototype	Both	Planning	Balancing / Network impact	Stochastic	Minimum time step of 1 hour	Economic model which aims at maximizing socio-economic surplus.	Electrical	Tested on systems comprising less than 100 bus bars and lines	DC LF		
OPAL/ SAMREL	SINTEF Energy Research	SINTEF Energy and Statnett. To be installed in Fingrid and Energinet	TSO	Planning	Mainly for detailed network impact, power market results are input.	Stochastic		Reliability indices including cost of energy not supplied are calculated.	Electrical	Limited by computer capacity (tested on nordic power system 3000 bus bars system)		Symmetrical load flow	
MODERNE	University of Strathclyde	University of Strathclyde	DSO	Multi-objective planning	Network Impact - DER integration	Stochastic / Statistical	Time-Step	Business case - trade off analysis of DER	Electrical	any distribution network		Symmetrical load flow	any distribution network
LV Planning	University of Strathclyde	University of Strathclyde	DSO	Planning	Network Impact	Stochastic / Statistical	Time-Step	Technical impact only at present	Electrical	any distribution network		Asymmetrical full load flow	any distribution network
HMms	University of Strathclyde	University of Strathclyde	Both	Operational market performance and planning	Market	Deterministic TS		Business case	Electrical /heat	any	DC LF		
HESA	University of Strathclyde	University of Strathclyde	DSO	Planning	Market / Network impact	Stochastic / Statistical	single point (time step to come)	End user costs present (FIT, feedback, grid electricity and gas costs). Societal - impact of community heating scheme	Electrical / Gas / heat	any distribution network	Bulk Energy Flows (elec, gas, fuel, heat, co2)		any distribution network
Probabilistic Load MODELLING	University of Strathclyde	University of Strathclyde	DSO	Could be used for day ahead operational	Market / Network impact	Statistical		Technical Impact. Societal Impact (Quantifying Behavioural Change)	Electrical / Gas / heat	any distribution network			any distribution network
CEEMU	TECNALIA	TECNALIA	DSO	Planning	Market	Stochastic	1 hr	Business case. Social benefit	Electrical / Gas		No network model		
VPP	TECNALIA	TECNALIA	DSO	Operational	Network impact	Deterministic	1 hr	No economic calculation	Electrical	Same as allowed by simulation tool used		Same as allowed by simulation tool used	1
MST	TECNALIA	TECNALIA	DSO	Operational	Market / balancing	Deterministic	1 hr	Business case	Electrical		No network model		1
Flexibility forecasting tool	TECNALIA	TECNALIA		Planning	Balancing	Stochastic	1 hr	Business case	Electrical		No network model		1
IPSYS	DTU	DTU, will be open sourced	DSO	Operational	Balancing / Network impact	Deterministic	60s-1h	No economic calculation	Electrical / Gas / heat	memory		Symmetrical load flow	

BASIC INFORMATION			SCOPE OF TOOL	PRIMARY PORPUSE OF MODEL	MODEL CONTEXT	MODELLING TYPE		ECONOMICS	ENERGY SUB SYSTEM MODELLED	ELECTRIC GRID MODEL			
			What level of voltage the system is studied (DSO/TSO)	Is the primary MODELLING time horizon of the tool	context: market interaction, system balancing or network impact	What is the MODELLING concept applied. Is it a deterministic TS model, stochastic time series, statistical with distributions as input and output		Is the simulation a purely technical simulation, is it calculating the impact of a particular implementation or impact at the society level	Which subsystems of the energy systems are included in the tool	How is the electrical network modelled: Size of system	Grid MODELLING	AC Load flow	Voltage levels
Name of tool	**Developer**	**User**	**TSO/DSO level**	**Operational /Planning**	**Market/ Balancing /Network impact**	**Deterministic/ Stochastic / Statistical**	**Time Step**	**No economic calculation /Business case/ social benefit**	**Electrical / heat / gas/ other**	**Max number of BUS LINES/GENERATORS/ CONSUMERS/ CONTROLLERS**	**No network model /DC load flow**	**Symmetrical/ asymmetrical load flow**	**number of voltage levels**
Flextool	VITO	VITO	not relevant	Operational	Market	Statistical		Business case	Electrical	Not relevant			
Intelligator	VITO	VITO	Both	Operational	Balancing / Network impact	Deterministic		No economic calculation	Electrical	Not relevant			
Power Matcher	VITO	VITO	Both	Operational	Balancing / Network impact	Deterministic / Stochastic	1 minute	Business case	Electrical / Gas / heat	Limited by computer capacity			
Fi.Si. (Field Simulator)	RSE	RSE	DSO	Operational	Network impact	Deterministic	Time-step	Business case	Electrical	Limited by computer capacity		Symmetrical load flow	as user defines
Ma.Re.	RSE	RSE	DSO	Both	Network impact	Deterministic		No economic calculation	Electrical	memory		Asymmetrical full load flow	2
MONET	RSE	RSE		Planning	Market / balancing	Stochastic		Economic calculation / business case / social benefit	Electrical / Heat	memory	No network model		
SPREAD	RSE	RSE	DSO	Planning	Network impact			Technical assessment / business case	Electrical	memory		Symmetrical load flow	2
VoCANT	RSE	RSE	DSO	Operational	Market / Network impact	Deterministic	Time-step	Technical assessment / business case	Electrical	memory	AC OPF	Symmetrical load flow	3
SCUDO	RSE	RSE		Operational	Market	Stochastic		Economic calculation / business case / social benefit	Electrical	memory	No network model	Symmetrical load flow	

Table 8 – Tool comparative table (part 2)

BASIC INFORMATION			SMART GRID CONTROL				SOFTWARE CHARACTERISTICS					Validation
							General information on the software					
			Control model	Base unit of controller	Granularity of MODELLING of smart grid control	Type of control	Availability	Platform	Type of product (library/stand alone)	Uses third part software	Data input/output compatibility	Has the tool been validated/verified
Name of tool	**Developer**	**User**	**Control model**	**Appliance/ microgrid**	**Local/ aggregated**	**Direct / indirect/ market based**	**Free / Commercial**	**WIN / MAC / Linux**	**Library / Stand alone**	**Third part software - which one**	**XLS / DB / CSV / XML /CIM**	**Yes / No**
LDM-SG	IPE (Institute of Physical Energetics)	IPE	Optimization	Microgrid (house)	local		Commercial	Windows	Stand alone		XLS /DB / CSV	yes, Latvian western networks
eTransport	SINTEF Energy Research	Research prototype with license for external use					Free	Windows	Stand alone	MS Visio, AMPL and CPLEX/COIN LP Solver	XLS / DB	Used in a number of municipalities with real data but not validated against meas
Samnett	SINTEF Energy Research	TSOs, Producers					Commercial	Windows	Stand alone	NAG library, COIN LP solver		Yes. Backtested against observations in the Nordic power market.
Prodnett	SINTEF Energy Research	Research prototype					Commercial	Windows	Stand alone	CPLEX/COIN LP Solver		Tested on a model of the Icelandic Power system
OPAL/ SAMREL	SINTEF Energy Research	SINTEF Energy and Statnett. To be installed in Fingrid and Energinet					Comm (research)	Windows	Stand alone or extension of Samlast/Samnett and PSS/E	Matlab and Matpower or PSS/E	XLS	Tested on reliability test systems (compared with digsilent)
MODERNE	University of Strathclyde	University of Strathclyde	OPF and DER location curtailment	DER	flexible	Direct	Private use	Windows	Stand alone	Matlab	XLS	yes - tba
LV Planning	University of Strathclyde	University of Strathclyde	Flexible	flexible	flexible	flexible	Private use	Windows	Stand alone	Matlab	XLS	yes - tba
HMms	University of Strathclyde	University of Strathclyde			flexible	market based control	Private use	Windows/Mac/Linux	Can be stand alone			yes - tba
HESA	University of Strathclyde	University of Strathclyde	DER location and dispatch	flexible	flexible	flexible	Private use	Windows	Stand alone	Matlab	XLS	yes - tba
Probabilistic Load MODELLING	University of Strathclyde	University of Strathclyde	Not applicable				Private use	Platform Independent	Library		DB / CSV	yes - tba
CEEMU	TECNALIA	TECNALIA	No Control model				Private use	Windows/ Linux	Stand alone	Excel	XLS	Yes
VPP	TECNALIA	TECNALIA	Load flow model		Individual units		Private use		Stand alone	PSS/E		No
MST	TECNALIA	TECNALIA		Microgrid	Both	market based control	Private use		Stand alone		CSV	No
Flexibility forecasting tool	TECNALIA	TECNALIA		Appliance	Aggregated	market based control	Private use		Stand alone	No	DB	No
IPSYS	DTU	DTU, will be open sourced	No particular control assumed, Flexible	Microgrid (house)	Individual		Open source	Windows/ Linux	Stand alone		CSV / XML	Yes, Faroe Island
Flextool	VITO	VITO	Optimization	Appliance	Aggregated		Private use	Windows/ Linux	Stand alone	No	XLS/ CSV/ XML	Yes
Intelligator	VITO	VITO	Market based control	Appliance	Aggregated	market based control	Private use	Windows/ Linux	Stand alone	No	XLS/ CSV/ XML	Yes, third part audit
Power Matcher	VITO	VITO	No particular control assumed, Flexible	Appliance	Aggregated	Direct / market based control	Free (open source)	Windows	Stand Alone	No	XLS/ CSV/ XML	Yes, field test
Fi.Si. (Field Simulator)	RSE	RSE	No particular control assumed, Flexible	Microgrid	Individual	Direct	Free (used by RSE)	Windows	Stand Alone	No	XLS/ CSV/ XML	Yes, Milan area
Ma.Re.	RSE	RSE	No particular control assumed, Flexible	EV charging station	Individual		Free (used by RSE)	Windows	Stand Alone	No	XLS/ CSV/ XML	Yes, Milan area
MONET	RSE	RSE	No particular control			market based control	Free (used by RSE)	Windows	Stand Alone	No	XLS/ CSV/ XML	Yes,20-20-20 burden sharing
SPREAD	RSE	RSE	Flexible	Appliance	Individual	Direct	Free (used by RSE)	Windows	Stand Alone	No	XLS /DB / CSV / XML	Yes, real Italian MV network
VoCANT	RSE	RSE	Optimization	Appliance	Both	Direct	Free (used by RSE)	Windows	Stand Alone	Matlab	XLS/ CSV/ XML	Yes, real Italian MV network
SCUDO	RSE	RSE	implicit	Appliance	Aggregated	market based control	Free (used by RSE)	Windows	Stand Alone	No	XLS / CSV	Yes, impact of Italian tariff