DEVELOPMENT OF SMART MICROGRIDS, A SMART GRID BASE

DEZVOLTAREA MICTROREŢELELOR INTELIGENTE, BAZA REŢELELOR INTELIGENTE

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Abstract: *Increase of digitalisation in building management along with growing accessibility of renewable energy sources represent an active domain with an accelerating trend at international level. Microgrids are a valuable technology for future energy supply systems, making the transition to Smart Grid and targeting real-time assessment and optimisation of energy efficiency.*

Keywords: Microgrid, Smart Grid, Smart Controller, Microgrid Software Tool

Abstract: *Creșterea digitalizării în managementul clădirilor împreună cu accesibilitatea tot mai mare la sursele de energie regenerabilă reprezintă un domeniu activ cu o tendință de accelerare la nivel internațional. Microrețelele inteligente sunt o tehnologie valoroasă pentru viitoarele sisteme de alimentare cu energie, asigurând tranziția către Reţelele Inteligente și vizează evaluarea și optimizarea în timp real a eficienței energetice.*

Cuvinte cheie: Microreţea, Reţea Inteligentă, Controler Inteligent, Instrument Software destinate microreţelelor

1. Introduction

In order to meet the EU climate change and energy policy targets by 2030 [1], a major transformation of our electricity infrastructure is needed. Strengthening and modernizing existing grids is important for integrating an

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increasing amount of renewable energy production, improving network security, developing the internal energy market and increase energy efficiency. To achieve these goals, it is not necessary only to build new lines and stations, but it is essential to use the global electricity system more intelligently by integrating information and communication technologies (ICT).

"*Smart grid*" can be defined in a variety of ways. The following definition is proposed by the European Electricity and Gas Regulatory Group (ERGEG), which is also used by the Council of European Energy Regulators (CEER) [2]: A smart grid is an electricity grid that can effectively integrate the behavior and actions of all users connected to it - generators, consumers and both - to ensure sustainable, cost-effective energy systems with low losses and high levels of quality and security of supply and security. The main reasons for the development of the Smart Grid are energy efficiency and reliability, optimal management of existing resources and integration of renewable sources. Smart grid integrates smaller networks *(microgrids*), which can operate independently of the public electricity grid [3]. These microgrids can improve the efficiency of a local power grid when faced with a high energy need, thus avoiding power outages. The microgrid can eliminate the need to install additional power lines in areas where demand is high [4].

2. Related work

A microgrid is a localized group of sources and charges of electricity that operate normally connected and synchronous to the national network [5], but which can disconnect and become "islanded mode" - and can operate autonomously as dictated by physical or economic conditions. This way, a microgrid can effectively integrate various distributed generation sources.

In 2001 [6], Professor R.H. Lasseter of the University of Wisconsin-Madison proposed the concept of "microgrid". Later, the Consortium for Technological Solutions for Electrical Reliability and the European Commission also gave their definitions for a microgrid. In 2002, the National Technical University of Athens (NTUA) built a small microgrid laboratory project known as the NTUA Power System laboratory facility for tests on the control of distributed resources and multi-agent technology loading. In 2003, several demonstration projects were built around the world, including the 7.2 kV microgrid in Mad River Park, Vermont, USA, the 400 V microgrid in

Kythnos Islands, Greece, and the Aichi, Kyotango and Hachinohe projects in Japan.

At the moment there are countless projects [7] that show the efficiency and durability of the solution, and the level of innovation has increased with the technical requirements that the microgrid must meet the following:

- **Flexible**: meet consumer needs by responding to changes [8];
- **Accessible**: to allow access to all users, especially to renewable and local sources with low or even zero carbon emissions;
- **Reliable and Resilience**: to ensure and improve the security and quality of energy supply [9], in accordance with current requirements, especially of computing technology, while avoiding incidents and uncertainties;
- **Economic**: to ensure low prices by introducing innovations, efficient energy management, competitiveness and efficient regulations [10].

3. Analysis of available commercial solutions

A. Investment decision support and optimization tools [11]

Table 1 - *Decision support and optimization tools*

	DER-CAM	**HOMER**	**RETScreen**
Load management strategies available	Demand response, Directly controllable loads, Load shifting, Resiliency-outage costs, Utility outages, Load prioritization, Curtailments	Deferrable electric loads, Optional electric loads	Power plants, electricity production heating, cooling, industrial, commercial, residential
Distributed generation technology capabilities	PV, solar thermal, wind turbines, fossil fuel generators, fuel cells, CHP	PV, wind turbines, run-of-river hydro power, fossil fuel generator, biomass, biogas, boiler, fuel cell, CHP	PV, wind turbines, run-of-river hydro power, fossil fuel generator, fuel cell, CHP, engines, refrigeration, pumps
Outputs	Optimal system configuration, Optimal placement of DER, Optimized strategic dispatch of all DER, Fuel consumption, Energy flows, Net present cost, Levelized cost of energy	Optimal system configurations, Fuel consumption, Energy flows, Net present cost, Levelized cost of energy, Capital costs, O&M costs	system configuration, investment, equipment sizing and performance monitoring, energy saving analysis, summary of fuel

			comparison, GHG emissions analysis, financial viability

The main benefit associated with the implementation of a microgrid is given by the increase of energy independence of the unit it serves (medical center, office building, data center, production space, etc.), allowing power from multiple sources, both renewable and fuel-based fossils, independent of the national network.

Currently there are tools for sizing, simulation, modeling of microgrids, which take into account more data than usual such as the proposed energy consumption, location of the site and the cost of the system. For microgrid projects, comparisons between communication mode, modules, converters and configurations of thousands of items in the database is no longer a difficult topic to address. Modules such as street-level climate locations, 2D graphic and photographic roof and floor layout, 2D shading with digital import from site surveys or online databases, design unlimited photovoltaic systems for 2D array number they are already basic subsystems. Below is a comparison of these software.

B. Microgrid modelling and simulation tools based on Matlab and Simulink

Table 2 - *Tools based on Matlab and Simulink*

	Typhoon HIL	**OPAL-RT**	**RTDS Simulator**
Hardware Description	This simulator has additional interface card for external communication like HIL DSP interface card, HIL uGrid interface card, HIL calibration card and HIL Breakout Board. This simulator has three different configurational	General-purpose multicore multithread CPUs are built-in to this simulator. The cores of each target system can be extended by using a multi-CPU motherboard, because each subsystem needs an	The RTDS Simulator hardware is designed with custom parallel processing architecture assembled in a modular unit called rack. This simulator is architected with many slots as well as

	mainly HIL402 and Microgrid HIL	individual core to execute the model.	with rail-mounted cards
Software Description	The operating system of the Typhoon HIL host is based on Windows. For the application interface, The Typhoon HIL software toolchain includes Schematic Editor, HIL SCADA, TEST SUITE and Power system TOOLBOX. It also has a communication interface with MATLAB. HIL SCADA visualize the test results using Python programmable action buttons.	The target of this simulator is developed with Linux-based operating system like QNX. The Operating system supporting the function required by real-time modeling.	Usually, operating system (OS) of the real-time simulators are designed using Windows or Linux platform. For specialized hardware, each vendor provides OS. In RTDS simulator, PB5's processor card is based on proprietary bare metal OS.
Communication Protocol	Typhoon HIL Simulator upports almost all modern communication protocols. The most common form of communication protocol is with Gigabit Ethernet PCIe based protocol. It also supports ModBus, IEC 61850, SunSpec etc	Nearly every modern engineering system employs some sort of critical, digital communication protocol. Similarly, OPAL-RT simulators use almost all industry-standard communication protocols, enabling users to perform the most realistic real-time simulations possible	It is a Ethernet based communication link. With the application demand, other protocols can be designed with the GTNETx2. Communication Protocols like MODBUS, TCP/UDP socket communication, IEEE C37.118, IEC 61850, IEC 61850-9-2

C. Support for advanced analytics, Digital Twin and IoT integration

Table 3 - *Support for advanced analytics, Digital Twin and IoT integration*

	Siemens MindSphere	**ThingWorx**	**ANSYS**
Features	Open Standard, Plug & Play, Cloud Infrastructure, Open Interfaces, Transparent Price, Model	Real-time Asset Monitoring, Operations/Manufacturing, Service/Support, Predictive Monitoring and Service, Connected Field Service, Product Development, Usage-Based Requirements, Define and trigger analysis events, Map incoming data to model	Asset Monitoring, Operations/Manufacturing, Service/Support, Predictive Monitoring and Service, Connected Field Service, Product Development, Usage-Based Requirements
Description	The whole idea behind MindSphere is to allow interconnectivity at the maximum possible level. Siemens has used open source standards & interfaces to make this a reality as PLCs, OPC UA, Modbus RTUs, etc.	OPEN Platform enables development of connectors for analysis tools. Connectors can be developed by partners or solution developers. Built on the ThingWorx platform enabling analysis models to be driven by real time sensor information. Configured per analysis provider.	Library supports multi fidelity modeling for electrification, applications and complements Twin Builder's high fidelity, ROM based workflow, Library of models to capture electrical, thermal, mechanical and controls interactions for electrification applications including electric and hybrid vehicles, electric mobility auxiliary power electric storage and electrification

D. Sizing and design

Table 4 - *Software for sizing and design*

	PVsist	**PV*sol**	
Functionality	System design, System sizing,	Design and simulation software	Sizing, financial analysis and single-

	Shading Scene, Simulation & Results, Grid Storage, Meteonorm, Components, Ageing, Bifacial, Batch, Economic evaluation	for photovoltaic systems, Simulation of different system types, Simulation of different installation types, Import of 3D Models, Import of satellite maps (3D), Use of online databases, Simulation with different parameters	line diagrams in a single solution, which can use in every situation and for all kinds of needs: for PV systems installed on new or existing buildings or even for large systems (photovoltaic farms), in every location
Distributed generation technology capabilities	The total energy production [MWh/y] is essential for the evaluation of the PV system's profitability, Performance Ratio (PR [%])	PV*SOL is a dynamic simulation program for the design and optimization of photovoltaic: Definition of high and low tariffs- high and low tariffs and definition of tariff times for reference and net metering tariffs; Detailed presentation of results	3D modeling of parametric PV system objects, even starting from DXF or DWG CAD drawings or BIM models, Solar irradiance data acquired directly from Meteonorm™ or PVGIS™ climatic databases, Calculation of photovoltaic shading

4. Application for microgrid modelling, design and implementation

Modelling and simulation of renewable energy production and consumption is an essential task of integrating microgrids in current applications in the energy field. Many of the programs specified above in category D are relatively simple and allow the user to automatically solve energy balance calculations, considering different components of the photovoltaic system. Professional and customizable report or how to view a detailed energy balance with all stage losses is a basic structure for them.

The Smart Microgrid Controller project (ID: 2020/505837), supported by the Norway grant through the Norwegian Financial Mechanism 2014-

2021, in the frame of the Green Industry Innovation, Blue Growth and ICT Programme Romania, proposes a practical approach for the development of such an intelligent microgrid. In this project company SIS S.A. (www.sis.ro) developed a methodology for microgrid design and computing of impact indicators, and, together with its partners, Monsson, Politehnica University of Bucharest and Accept S.RL., works on the implementation of such a system. The solution integrates solar panels with a totally installed power of 120 kW, two storage units of different capacities (40 kWh and, respectively, 56.3 kWh) and a gas-engine generator of 50 kVA. The microgrid was designed for the Monsson office building. A controller developed by SIS using Siemens S7-1500 hardware platform will allow monitoring and control of system elements to ensure an efficient use of available energy supply and storage resources and to optimize according to a cost constraint the total energy supplied from the national grid.

In this project, the PV*sol calculation program was used, with a package designed for the study, sizing and analysis of data and the calculation of photovoltaic performance according to EN 15316-4-6. The photovoltaic systems that can be analyzed using this program are dynamic simulation with 3D visualization and detailed shadow analysis for the calculation of photovoltaic systems in combination with appliances, battery systems and electric vehicles. For analysis, online databases are used for both cost and existing meteorological data globally, as well as databases containing detailed specifications of system components. This software has various modules that can contain valuable information for architects, engineers, researchers and also help in the educational field.

The innovation of this software is represented by the ability to form a microgrid and / or a smart local energy system (SLES) because it incorporates components such as the integration of the domestic hot water system with a thermal profile. This subsystem is used for simulations of different types of systems, different types of installations, different parameters, etc. In addition, power disconnect algorithms are found to reduce network exports when limited, and customizable data import load profiles with smart meter can be chosen.

The software has 3 levels of expertise for sizing a photovoltaic system, each level being corresponding to the various stages in the development of a real system.

Preliminary design - corresponds to the pre-sizing stage such as sizing of DC or AC cables (calculation of cable losses per inverter, definition of electrical protection devices), evaluating system performance using monthly average values, defining the consumer and consumption curves, using several parameters without specifying the system components. The tracking of the Sun's route can be modeled in different orientations, including the single North-South axis; The single East-West axis; Single vertical axis of rotation; and the double axis.

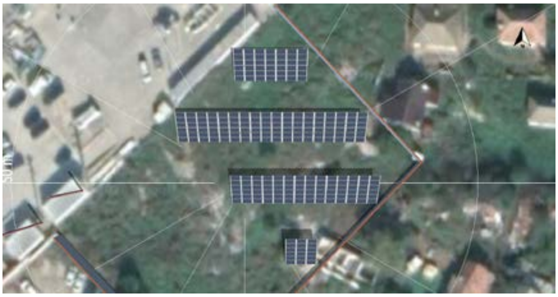

Figure 1 - Project overview

General Data
PV Generator Output 127.26 kWp; PV Generator Surface 607.3 m²
Number of PV Modules 252; Number of Inverters 1
PV Generator, 1. Module Area - Arbitrary Open Surface 01-Mounting Surface South
Name Arbitrary Open Surface 01-Mounting Surface South
PV Modules 252 x TSM-DEG18MC.20(II) – bifacial (v2); Manufacturer Trina Solar
Inclination 25 °; Orientation South 180 °; Installation Type Mounted - Roof

With just a photo of the PV location and the main dimensions, it was possible to create a realistic representation of the property, with an image on the placement of each PV string.

Project design - simulations of the system can be performed and can be compared after the stage of defining the orientation of the plan and the choice of different specific components of the system, but also determining the optimal load. String planes can be generated, as shown below in 2D dimension, while the cabling plane emerges.

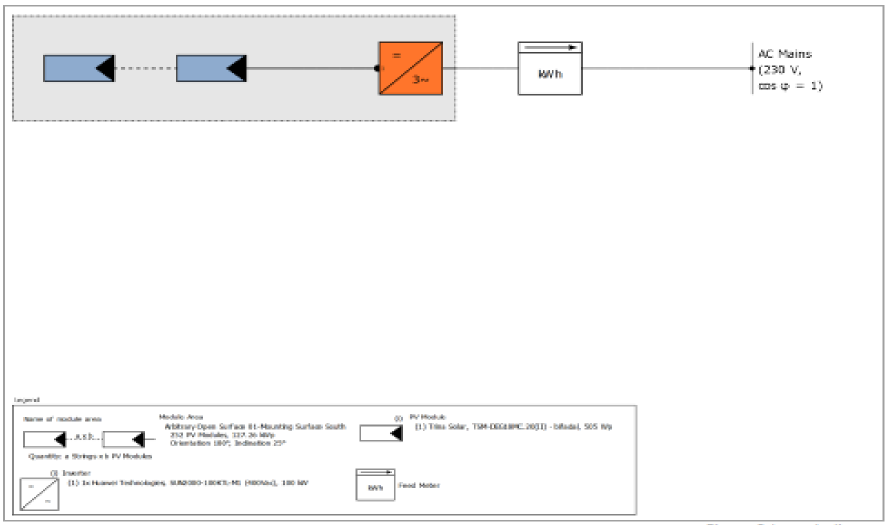

Figure: Schematic diagram

Figure 2 - Schematic diagram

PV Generator Energy (AC grid) 176,308 kWh
Grid Feed-in 176,308 kWh
Down-regulation at Feed-in Point 0 kWh
Own Power Consumption 0.0 %
Solar Fraction 0.0 %
Spec. Annual Yield 1,385.42 kWh/kWp

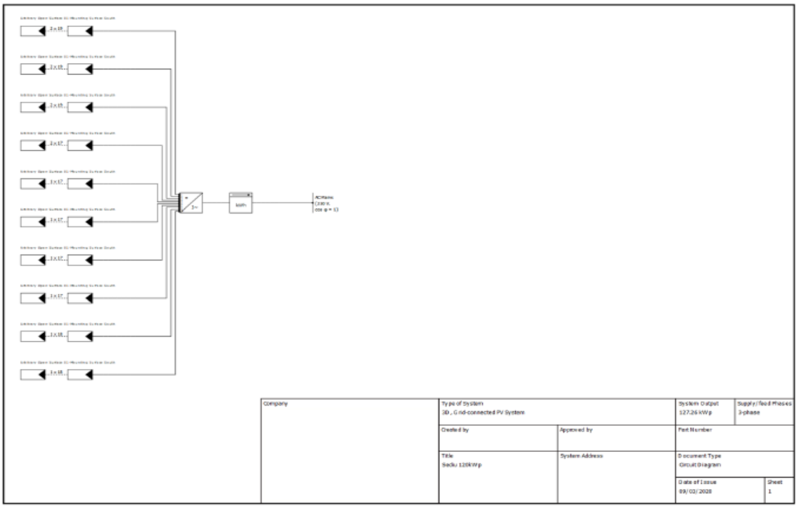

Figure 3 - Plans and parts list - Circuit Diagram

The software provides the possibility to compare solutions with each other, in a tabulated interface of the parameters. The program

helps the user in sizing the system (number of modules used and their arrangement - in series or in parallel), taking into account data related to inverters, batteries or project needs.

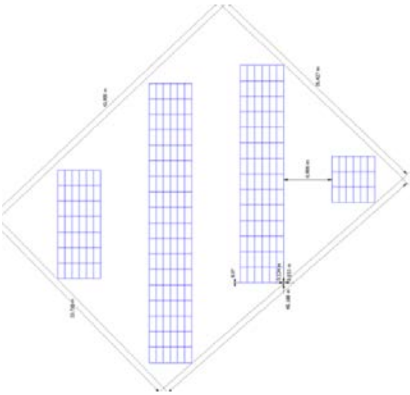

Figure 4 - Dimensioning Plan

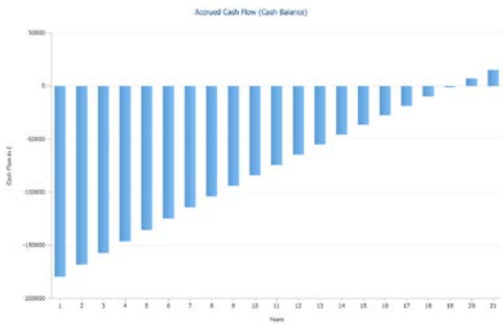

Figure 5 - Financial analysis

A rough estimate from a **financial** point of view is also made. Data related to cost, tasks, discount, currency depreciation and tax payments were provided in the software application, and the range of values framed by the beneficiaries was mentioned.

Total investment costs 190,890.00 £
Return on Assets 1.65 %
Amortization Period 19.2 Years
Electricity Production Costs 0.06 £/kWh
Performance Ratio (PR) 81.6 %
Yield Reduction due to Shading 1.7 %/Year
CO_2 Emissions avoided 82,865 kg / year

5. Conclusion

1. Developers, manufacturers and researchers are investing resources to bring innovative solutions to the market, to support sustainability, to increase resilience and energy independence, and also to reduce the degree of pollution and greenhouse gas emissions. It is necessary to use more than one software for data analysis in each case study, because those differences in results will be seen.
2. However, from the analysis performed, PV * sol is a software that strengthens the trust of the data, and is the closest to the real data in the field. The fact that real data could be compared with simulated data is a strong benefit.

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