INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P)
http://www.ijmp.jor.br *v. 12, n. 5, July-August 2021*
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i5.1379

OVERVIEW ON MODELING AND MANAGEMENT OF SMART GRIDS

Jihen Elkhaldi
ENICathage, University of Carthage, Tunisia
E-mail: jihenelkhaldi@yahoo.com

Lotfi Bouslimi
ENICarthage, University of Carthage, Tunisia
E-mail: lotfi.bouslimi@enicarthage.rnu.tn

Hamza Wertani
ENICarthage, University of Carthage, Tunisia
E-mail: hamzawertani22@gmail.com

Mohamed Najeh Lakhoua
ENICarthage, University of Carthage, Tunisia
E-mail: MohamedNajeh.Lakhoua@ enicarthage.rnu.tn

Submission: 6/25/2020
Revision: 7/30/2020
Accept: 9/8/2020

ABSTRACT

The concept of Smart Grids refers to a complex ecosystem that can be described as a combination of systems to capture its most structural elements. When studying these complex systems, the traditional tools of the Cartesian methods have shown their limits. There is therefore a need to resort to other methods to model them.

These modeling methods are generally classified and grouped into five families: functional modeling, decision modeling, resource modeling, information modeling and mixed modeling. This review provides an overview of the state of the art of an intelligent network. The classification of modeling methods is also presented. Then an application of the bond graph approach will be explained. Finally we describe a general idea on the management of smart grids.

Keywords: Smart Grid, modeling methods, classification, management

[https://creativecommons.org/licenses/by-nc-sa/4.0/]
Licensed under a Creative Commons Attribution 4.0

http://www.ijmp.jor.br v. 12, n. 5, July-August 2021
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i5.1379

1. INTRODUCTION

Around the globe an adjustment of electric energy is required to limit CO_2 gas emission, preserve the greenhouse, limit pollution, fight climat exchange and increase energy security (Ourahou et al., 2018). The solution will come from renewable natural energies considered inexhaustible, and in addition they produce neither toxic waste, greenhouse gas nor nuclear wast, etc.

By consequences, most of the current electricity grids have to change if they are to support the transition to a renewable based energy system.

This change will be based on the progressive development of a new "intelligence" of the electrical system, based on a greater penetration of new technologies, which may be the solution for the above problem: smart grid technologies (Weedall, 2000).

The smart grid technologies can also allow the allocation of large amounts of renewable-based power generation.

Despite the many benefits they bring, renewable energy has also some flaws that should not be neglected. The most important is the irregularity of electricity production over time. This problem with variable and unsecured power can be solved by a coupling of supply sources and the formation of a hybrid system.

2. GENERALTIES ON SMART GRIDS

Smart grids can be defined as the integration of electric grids, communications networks, specific hardware and computational intelligence (algorithms) to monitor, control, and manage the generation, distribution, storage and consumption of energy. The smart grid of the future will be distributed, interactive, self-healing and communicating with every device (Carvallo & Cooper, 2011).

A smart grid is an umbrella term that covers modernization of both of the transmission and distribution grids (Figure 1).

[https://creativecommons.org/licenses/by-nc-sa/4.0/]
Licensed under a Creative Commons Attribution 4.0

http://www.ijmp.jor.br v. 12, n. 5, July-August 2021
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i5.1379

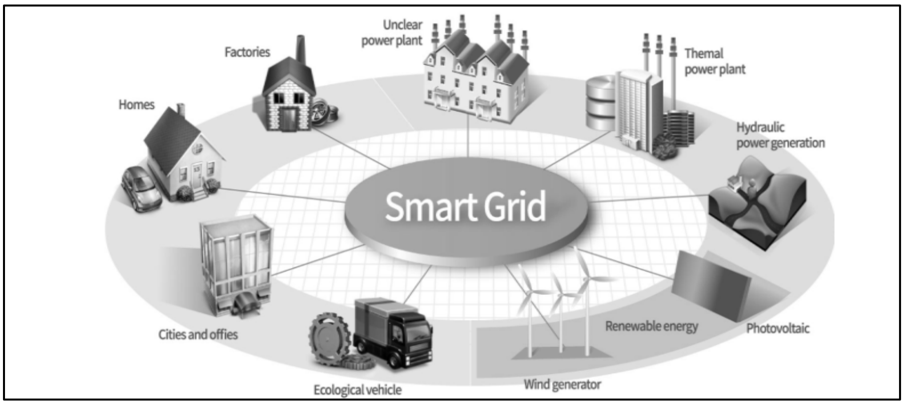

Figure1: Model of a smart grid
Source: Gungor et al. (2011).

2.1. Architecture of smart grids

The architecture of Smart Grids can be divided into three levels:

- A first layer of infrastructure composed of equipment used to carry electricity (lines, transformers, etc.).
- A second level formed by communication architectures (multi-media and multi-technologies) collecting data from different network sensors.
- A final level consisting of applications and services, such as monitoring, remote intervention systems, and automation of electricity demand responses using real-time information.

2.2. Objectives of smart grids

The main objectives expected of smart grids are (Jabban, 2013):

- A high capacity to introduce new services.
- Reduced time and cost of development.
- New functions introduced within the network to allow each user to personally manage their data.

Like any complex system, an intelligent network consists of a large number of interacting entities. It adapts to external or internal pressures to maintain its functionality. This complexity contributes to the emergence of the modeling.

In order to ensure efficient modeling and rapid optimization of Smart Grids, we need to study them systemically to define and understand the characteristics and behaviors of each component of the global system.

And to do that, there are different methods, and a multitude of application domains.

[https://creativecommons.org/licenses/by-nc-sa/4.0/]
Licensed under a Creative Commons Attribution 4.0

INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P)
http://www.ijmp.jor.br v. 12, n. 5, July-August 2021
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i5.1379

3. MODELING METHODS

Modeling a system before it is made allows a better understanding of how the system works. It is also a good way to control its complexity and ensure its consistency (Figure 2).

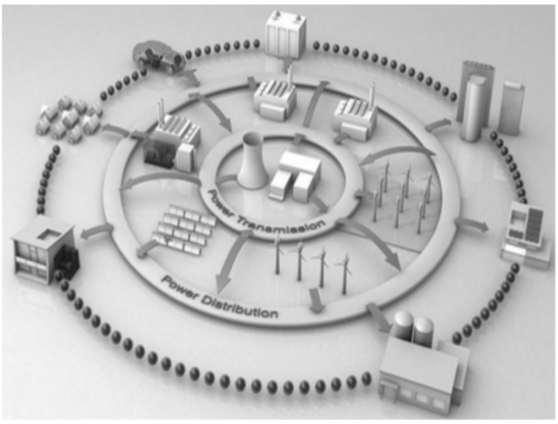

Figure 2: Example of modeling a smart grid

Modeling methods are generally classified and grouped into five families: functional modeling, decision modeling, resource modeling, informational modeling and mixed modeling.

3.1. Functional modeling

Function-oriented modeling describes the functions, activities, and designed process of a system. Functional modeling methods represent the interactions between functions and activities by describing the information exchanged between them and the resources used and proceed to their decomposition in an organized and detailed manner to better understand the functioning of a system (Rahmouni & Lakhoua, 2010).

Different methods have been used for the analysis and modeling of functions such as: SADT, IDEF family and Petri nets (Figure 3).

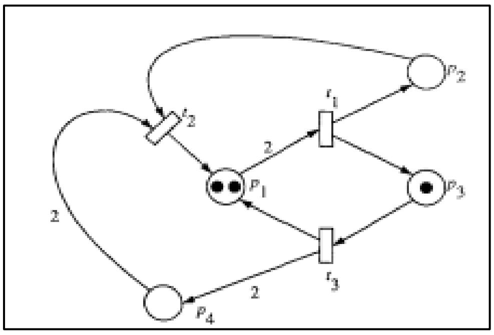

Figure 3: Example of a Petri net

Source: Rahmouni and Lakhoua (2010)

[https://creativecommons.org/licenses/by-nc-sa/4.0/]
Licensed under a Creative Commons Attribution 4.0

ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i5.1379

3.2. Decision modeling

This approach aims to provide a detailed description of the decisions to be made within a clearly defined time horizon and according to the activities.

The best-known decision-oriented modeling methods are GIM and its GRAI origin (Figure 4), originally developed by Professors Pun and Doumeingts at the GRAI research laboratory of the University of Bordeaux in the early 1980s (Hassan, 2010).

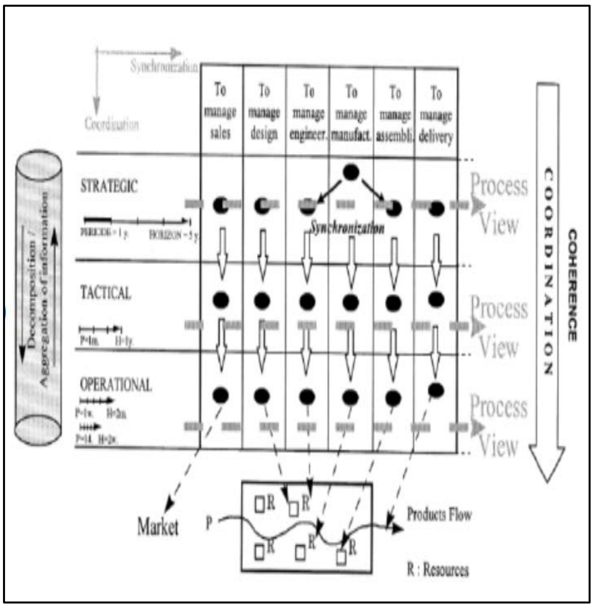

Figure 4: The GRAI reference model
Source: Kromm, Christophe and Deschamps (2004)

3.3. Resource modeling

Resource-oriented modeling methods allow the description of the resources required to carry out an activity by taking into account the constraints of allocation of these resources. They are specialized in the management of resources from its acquisition until its exploitation but without understanding their operation (Darras, 2004).

Among the methods of resource modeling, we consider the multi-agent approach, PERA (Figure 5) and MOVES.

[https://creativecommons.org/licenses/by-nc-sa/4.0/]
Licensed under a Creative Commons Attribution 4.0

INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P)
http://www.ijmp.jor.br v. 12, n. 5, July-August 2021
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i5.1379

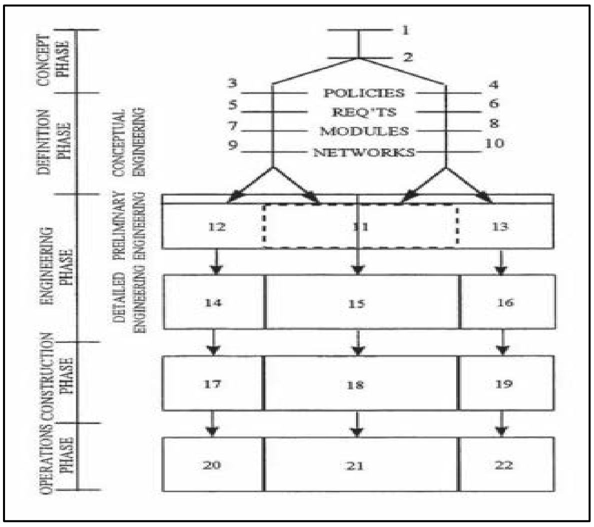

Figure 5: Skeleton of the PERA methodology
Source: Kosanke, Vernadat and Williams (1997).

3.4. Informational modeling

Informational modeling methods and process are intended to model the information system. They ensure the flow of information about the processes, functions, resources, organization, etc of a system. Some languages have been developed (Figure 6) to meet this need such as: UML, UEML and IEM.

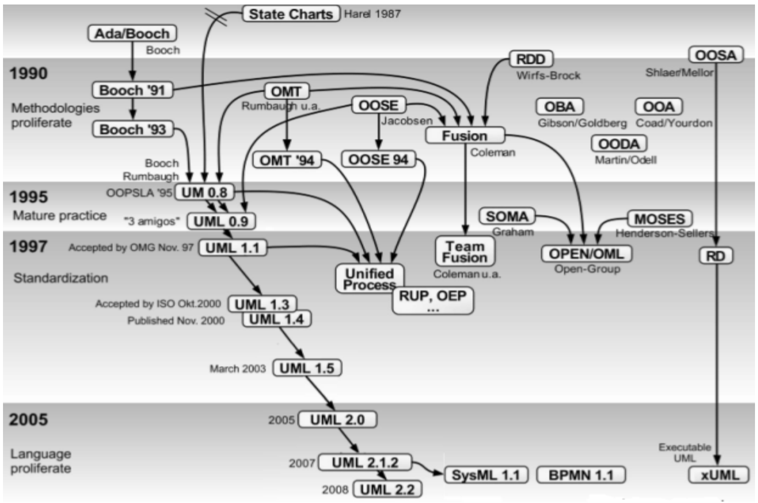

Figure 6: History of UML

3.5. Mixed modeling

A methodological approach is qualified as mixed when the researcher combines quantitative and qualitative data / methods in the same study.

This modeling technique studies the organization, the resources, and the information process models and quantitatively analyzes the running of a system.

[https://creativecommons.org/licenses/by-nc-sa/4.0/]
Licensed under a Creative Commons Attribution 4.0

http://www.ijmp.jor.br *v. 12, n. 5, July-August 2021*
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i5.1379

Although they cover several aspects and study various systems (functional, informational, resource and organizational). Mixed modeling methods cannot model decision-making systems.

In the face of very rapid scientific progress, some modeling methods (such as Merise, Booch, etc.) have quickly shown certain limits. This evoked the birth of other methods (such as UML, SysML, etc.).

Others have shown great reliability in studying systems systematically, in order to extract the main characteristics and behaviors of the different elements making up the overall system.

In the next section, an approach to modeling an energy source (Wind Turbine) that is part of the global smart grid system to be studied will be presented.

4. WIND TURBINE MODELING APPROACH

4.1. Bond Graph approach

Bond graph is a graphical technique used to model systems with a unified language for all areas of the physical sciences (Dauphin-Tanguy, 2000).

We can combine different types of model systems such as electrical, mechanical, hydraulic, thermal in the same Bond Graph, allowing a graphic visualization of cause and effect, and provides power conservation (Table 1).

Table 1: List of applications and their benefits

Applications	Advantages
Modelization	Makes the energy study possible
Analysis	Simplifies model building for multidisciplinary systems
Control	Leads to a systematic writing of mathematical models (linear or non-linear associates)
Identification	Model estimation and identification of slow and fast variables
Surveillance	Study of structural properties
Simulation	Possibility to build a state observer from the model

4.2. Wind turbines

A wind turbine (WT) is a machine that transforms the kinetic energy of the wind into mechanical or electrical energy. The power recoverable by a WT is a function of the square of its diameter and the cube of the wind speed. This current is supplied to a converter which transforms the variable direct current into stable alternating current and supplies the building's electrical network or is stored in batteries.

[https://creativecommons.org/licenses/by-nc-sa/4.0/]
Licensed under a Creative Commons Attribution 4.0

ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i5.1379

4.3. Modeling of a wind turbine by Bond Graph approach

The modeling of a WT (Figure 7 and 8) can be divided into several sub-models as shown in figure 9. This includes the aerodynamic model, drive train model, and the generator model. The model of the generator is generally a PMSG type as induction type generators would require field supply from the grid. In terms of control, wind turbines are normally equipped with pitch angle control for maximum power extraction and converter control to provide control of output power (Lakhoua, Naouali & Chakroun 2014).

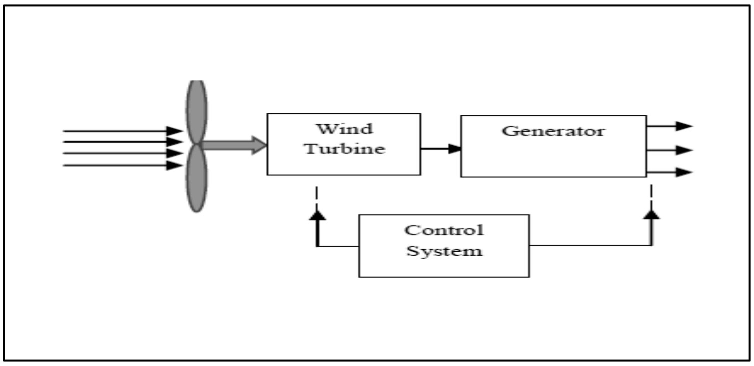

Figure 7: Bloc diagram of the WT

The aerodynamic model of the WT gives the amount of energy that can be extracted by the turbine from the wind. This is given in terms of the mechanical power extracted by the WT which is given as (Diaf, Belhamel & Haddadi, 2007):

$$T = \frac{1}{2\Omega_t} C_p(\lambda,\beta)\rho S V^3 \tag{1}$$

The blades of the WT extract the kinetic energy from the wind and converted mechanical energy.

The kinetic energy is equal to the mass of air m and the wind speed in the equation (2):

$$E = \frac{1}{2} m V^2 \tag{2}$$

The moving airpower is equal to:

$$P_w = \frac{dE}{dt} = \frac{1}{2} m V^2 \tag{3}$$

Where m is the mass flow rate per second. The air passes across an area A. From equation (4):

$$P_w = \frac{1}{2} m. A. \rho. V^2 \tag{4}$$

Where ρ is the air density (ρ = 1.225kg/m2). The power extracted from the wind by the blades:

[https://creativecommons.org/licenses/by-nc-sa/4.0/]
Licensed under a Creative Commons Attribution 4.0

http://www.ijmp.jor.br v. 12, n. 5, July-August 2021
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i5.1379

$$P_{Blade} = C_p(\lambda,\beta).P_w = C_p(\lambda,\beta).(0.5)m.A.\rho.V^3 \quad (5)$$

Where Cp is the power coefficient. The power coefficient is given to the function. β (in degree) is the pitch angle of the rotor blades. λ defines the tip speed:

$$\lambda = \frac{R\Omega_t}{V} \quad (6)$$

Figure 8 shows a sketch of a WT. It consists of six inertias which are; the three blades, hub, gearbox and generator. The inputs are wind speed and electromagnetic torque. To derive the dynamic equations for this model using Newton's second law can be quite hard, and one can easily make some mistakes (Diaf, Belhamel & Haddadi, 2007). This is why the differential equations are derived for the simplified case. The different parameters are explained in Figure 9 shows a three-mass sketch of a WT.

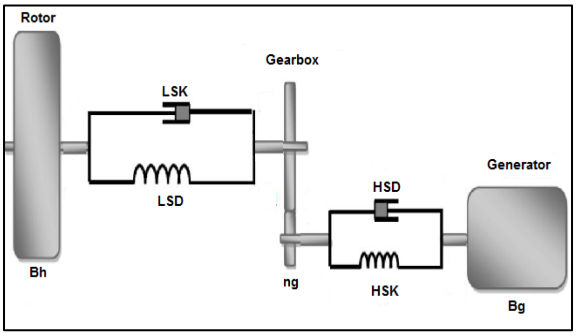

Figure 8: Model of the WT

The sketch consists of a hub, gearbox, and generator. Inputs are aerodynamic torque and electromagnetic torque.

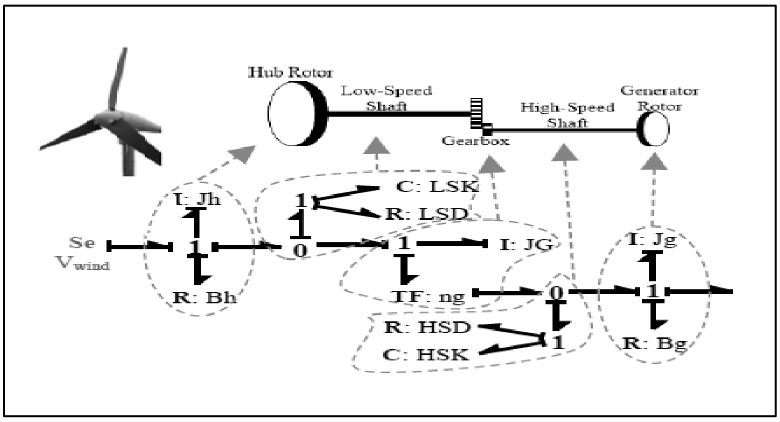

Figure 9: Assemblage bond graphs of the WT

A model of a flexible WT is built by using the bond graph method; we introduced in this model the flexibility of blades, shafts, and the tower we finally got a complete model that describes the behavior of wholes the essential elements of the system and less difficult than other methods, in the future work we will analyze the behavior of the system and we will

[https://creativecommons.org/licenses/by-nc-sa/4.0/]
Licensed under a Creative Commons Attribution 4.0

ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i5.1379

compare it with a classical method to show the efficiency of this method and to study the interaction of the WT with the other systems.

4.4. Simulation

The simulation step is done on a specific bond graph software 20-Sim, which is an object-oriented hierarchical modeling software. It allows users to create models using bond graphs, block-diagram, and equation models.

In this simulation model case, a list of numerical values of WT system parameters is introduced in order to ensure a best simulations result. The different speeds (Hub, gearbox and generator) of the WT are presented in figure 10.

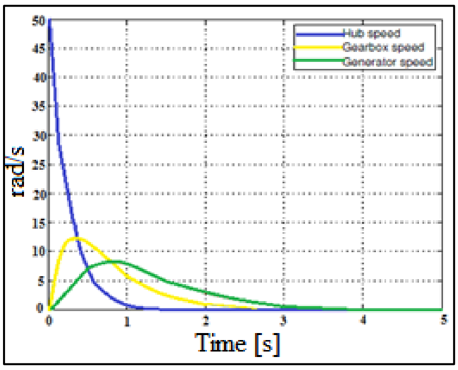

Figure 10: Results of the WT system speeds with respect to time(s)

The parameters introduced for the wind model are the pitch angle, the reference power and the wind speed. The simulations are made with a maximum pitch angle, a maximum wind condition, a maximum power and with initial conditions on the rotor and the wind generator. The result obtained is not so significant; it is just to validate part of the modeling approach by bond graph. There are still many future improvements in the coupling of the turbine with the converter and the intelligent control system to improve the performance of the electrical parameters (current, voltage and frequency) in the output of the system to be well usable to smart grids and consumers (demand side).

In the next section we will explore the concept of management and its importance between the distribution and the demand sides in the smart grid.

5. MANAGEMENT OF SMART GRIDS

The transformation of today's grid towards smart grid imposes modifications on the management of resources. A large part of the energies used by smart grids are renewable energies, which are characterized by their unpredictability. Consequently the distribution of

[https://creativecommons.org/licenses/by-nc-sa/4.0/]
Licensed under a Creative Commons Attribution 4.0

ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i5.1379

energy becomes more difficult. Therefore control methods are necessary to achieve implementation.

5.1. Demand side management

Demand side management (Rahman & Rinaldy, 1993; Cohen & Wang, 1988) is an important function in energy management of the future smart grid, which provides support towards smart grid functionalities in various areas such as electricity market control, and management, infrastructure construction, and management of decentralized energy resources. The primary objective of the demand side management techniques presented in the literature is reduction of system peak load demand and operational cost.

Demand side management commonly refers to programs implemented by utility companies to control the energy consumption at the customer side of the meter (Logenthiran, Srinivasan & Zong Shun, 2012).

There are several demand side management techniques and algorithms used in the literature (Cohen & Wang, 1988; Hsuand & Su, 1991).

5.2. Distributed side management

Distributed Side Management (DSM) control actions are implemented with the aim of reducing peaks in energy demand and to make the energy demand pattern flatter, either at a per-house or at a grid level. This is mainly obtained by avoiding the synchronous activation of appliances or loads and by optimizing their activation in order to achieve the overall better energy efficiency and by doing this in the most transparent way with respect to the end-users (Miceli, 2013).

In order to be deployed, these strategies have to be supported by specific appliances or house infrastructures, by suitable control algorithms.

6. CONCLUSIONS

Smart grids are the expression of the digital revolution in our energy grids and it is certain that they have started and will continue to change the entire value chain. They are not intended to replace the existing electrical network, but to improve it. The Smart Grid must reconcile internal emergence and self-organization by external factors in order to find the most optimal balance of energy distribution in real time.

The work carried out should make it possible to create a general model of smart grids. The analysis and optimization of these complex systems opens up new perspectives.

[https://creativecommons.org/licenses/by-nc-sa/4.0/]
Licensed under a Creative Commons Attribution 4.0

http://www.ijmp.jor.br v. 12, n. 5, July-August 2021
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i5.1379

Starting from this study of overview on modeling and management of Smart Grids presented in this paper, we will study and model an example of multi-source Smart Grid with different methods with the aim of optimising the consumption of electrical energy and improving the management of this energy from production to the consumer.

REFERENCES

Carvallo, A., & Cooper, J. (2011). **The Advanced Smart Grid**: Edge Power Driving Sustainability, Artech House, Boston.

Cohen, A. I., & Wang, C. C. (May 1988). An optimization method for load management scheduling, **IEEE Trans. Power Syst.**, 3(2), 612–618.

Darras, F. (2004). Thèse: **Proposition d'un cadre de référence pour la conception et l'exploitation d'un progiciel de gestion intégré**. Toulouse: Institut national polytechnique de toulouse.

Diaf, S., Diaf, D., Belhamel, M., Haddadi, M., & Louche, A. (2007). A methodology for optimal sizing of autonomous hybrid PV/wind system, **Energy Policy**, 35, 5708–5718.

Dauphin-Tanguy, G. (2000). «**Les Bond Graphs**»,: Hermès Science Editor.

Gungor, V. C., et al. (2011). Smart grid technologies: communications, technologies and standards, **IEEE Trans. Ind. Inform**. 529–539.

Hassan, A. (2010). Thèse: **Proposition et développement d'une approche pour la maîtrise conjointe qualité/coût lors de la conception et de l'industrialisation du produit**. Metz: École Nationale Supérieure d'Arts et Métiers.

Hsuand, Y. Y., & Su, C. C. (Aug 1991) Dispatchofdirectload control using dynamic programm.ing, **IEEE Trans. PowerSyst**., 6(3), 1056–1061.

Jabban, A. (2013). **Optimisation et analyse des résesaux intelligents et des réseaux hétérogènes**. Autre. INSA de Rennes.

Kosanke, K., Vernadat, F. B., & Williams, T. J. (1997). «**manufacturing entreprise modeling with PERA and CIMOSA**», IFAC manufacturing systems : Modeling Management nd control, vienna, Autria.

Kromm, H., & Deschamps, J. C. Modélisation de processus pour une évaluation par niveaux de détail successifs. **Conférence francophone de modélisation et de simulation**. Troyes (France)..

Lakhoua, M. N., Naouali, N., & Chakroun, A. (2014). System Analysis of a Hybrid Renewable Energy System, **International Journal of Electrical and Computer Engineering (IJECE)**., 4(3), 343-350.

Leeand, H., & Wilkins, C. L. (1983). A practical approach to appliance load control analysis: A waterheater case study, **IEEETrans.PowerApp.Syst.**, PAS-102(4), 1007–1013.

Logenthiran, T., Srinivasan, D., & Zong shun, T. (2012). Demand Side Management in smart grid using Heuristic optimization, **IEEE.transactions on smart grid.**, 3(3).

Miceli, R. (2013). Energy Management and smart Grids,**Energies**, 6, 2262-2290; doi:10.3390/en6042262.

[https://creativecommons.org/licenses/by-nc-sa/4.0/]
Licensed under a Creative Commons Attribution 4.0

ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i5.1379

Ourahou, M., Ayrir, W., El Hassouni, B., & Haddi, A. (2018). Review on smart grid control and reliability in presence of renewable energies challanges ns prospects, **science direct**.

Rahmouni, M., & Lakhoua, M. N. (2010). **Using function and decision models for entreprise restructing**, STA, Monastir.

Weedall, M. (2000). **BPA Smart Grid Overview**, Energy and Communications, Washington House Technology.

Rahman, S., & Rinaldy, S. (1993). An efficient load model for analyzing demand side management impacts, **IEEE Trans.PowerSyst.**, 8(3), 1219–1226.

Schweppe, F. C., Daryanian, B., & Tabors, R. D. (1989). Algorithms for a spot price responding residential load controller, **IEEE Trans. Power Syst.**, 4(2), 507–516.

[https://creativecommons.org/licenses/by-nc-sa/4.0/]
Licensed under a Creative Commons Attribution 4.0