Smart Grid Based Data Integration Platform and Constraints satisfaction for Optimal Managing of the Energy Distribution

Mostafa Ezziyyani(1), Loubna Cherrat(1), Said El Karimi, Mohammed Ezziyyani(2), Mustapha Diani(1), Mohammed Jbilou(1)
(1) *Abdelmalek Essaâdi University Faculty of Sciences et Techniques of Tangier*
(2) *Abdelmalek Essaâdi University Faculty Polydisciplinary of Larach*
ezziyyani@fstt.ac.ma

Abstract— **With the existence of several energetic resources and local production site by consumers a new strategy for managing the distribution of energy is indispensable. This paper aims to develop a simulation platform for energy resources management of a Micro Grids Network to optimize the electricity consumption. Using the remote control systems and data integration from distributed databases the system regulates automatically the distribution following the need of each customer and need of Micro Grid. The solution use an incremental search algorithm based on the total satisfaction of the constraints by priority order.**
In this paper, as software platform solution, we use the multi-agent system (MAS) technology. This choice is motivated by the functional ability of agents, and their self-adaptation to the environment (i.e. change the feature). The ability of the interaction between the agents and theirs mobility will define and specify the real-time needs of each Micro Grids according to its production and consumption capacity and the need of its neighbors. The functional architecture of the operating system is based on a graph, where each node can be a customer or producer of energy or both of them associated with list of requirement constraints. We used the principle of Distributed Databases to facilitate communication inter-agents and to optimize the time of data transfer between agents of different Micro Grids and simplified access "on demand" to the data with high availability. Thanks to the distributed databases solution, we can easily integrate the critical data on a data center and improve the response time of readjustment and equilibration of the electricity distribution and consumption.

Keywords (Optimization, Integration, Micro Grids, Data base, Big Data, Smart GRID, Energy, Agent, Real time, Constraints, PCC, Distributed Databases)

I. Introduction

Nowadays, the cost of energy resources becomes very high. Several countries spend the billions of dollars to find solutions to reduce this cost. This is usually done by the different ways: (1) the identification and development of new types of energy resources based for instance on solar and (2) the exploitation of the usage of consumers (housing, electrical vehicle, etc.) of energy to adjust their consummation. This solution is less costly than the previous one, since it can be implemented by educating the consumers and making her/him more sensitive on energy cost. To achieve the reduction of energy a solution combining these both solutions is more feasible.

In the meantime, a spectacular development of devices such as Smart Grids, sensors, tablets, smart phones, etc. may contribute in implementing solutions belonging to the previous categories (1) and (2). A Smart Grids contains advanced technology that enables enhanced, two-way communication between a utility and its customers. The resulting information provides customers with:

- Tools to help manage their energy
- Improved energy efficiency
- Improved reliability (fewer outages)

To manage perfectively the grid power generated through renewable generation sources, our project, entitled, SGiRE: "Smart GrId based Platform for Managing Renewable Energy" will serve as a blueprint for future Smart Grid implementation and will accelerate a realization of the "future Tool" safely delivers reliable electricity with greater efficiency and improved environmental performance. SGiRE will gain knowledge about customer (their profiles, consummation habitudes, etc.) needs and usage patterns. In addition, the Users of this tool will be able to gather information about Smart Grid's storage capabilities, supply and delivery.

The Smart Grid demonstration improvements will enhance service for the entire of the Micro Grids through improved service reliability, reduced energy delivery costs, more efficient energy consumption, and better information flow. Two basics feature:

- Smart Generation: The production cannot be carried out except if there is a need (Cost-effective solutions). The resources will be used to add renewable energy while reducing and shortening system outages.
- Smart Distribution: Develop the smart applications like automated meter reading, smart switches and smart capacitors. Improved customer delivery and service

quality will result from future advanced technologies. This also provides the ability to communicate with customers on prices and conditions of the system.

Smart Grid provides real-time information that increases awareness of electricity use and identifies opportunities to reduce consumption and save money. And, Can automatically set temperatures based on season, resulting in up to 20 percent savings in heating and cooling bills. And, Helps customers understand the impact of electricity use and encourages them to conserve energy, help the environment and save money.

One of the major attribute of the smart grid is to integrate renewable and storage energy resources at the consumption premises. This project seeks design, implementation and testing of a system that integrates renewable and storage energy resources to a smart home. The proposed system provides and manages a smart home energy requirement by installing renewable energy.

So implement wireless sensor network (WSN) technology to communicate control information among different components (solar energy generator, inverter, energy storage and conditioning, appliances, smart meter, etc.).

Interfacing renewable energy generator with the smart grid is an optimization problem that seeks to find the optimum solution among three conflicting parameters which are local generation (solar energy), local utilization, and external grid state (stability). The wireless sensor network needs to implement novel algorithms that will find the optimum state where the system is stable. A research question that will see to answer is how different components will communicate and does the health of the solar energy generator allow the energy to be flowed to the grid? If there is a surplus in the grid power, what is the optimum operational mode of the renewable generator given the local energy consumption and the state of the grid?

The main thrust of this project is that design and development a distributed system based on SMA technology with real interaction with WSN. That will enable the communication among different components as well as providing the processing capabilities to implement the algorithms necessary to coordinate and optimize the operation of the system as a whole.

II. MOTIVATION AND IMPACT ON SOCIO-ECONOMIC

Today in Morocco, and like all other countries, energy is more expensive. The big concern is, the search for sustainable sources of energy, cheaper and less polluting. The solution converges to renewable energy, not centralized in nature, challenging the old logic. The kilowatt cleanest and cheapest being the cause. In addition, the development of digital technologies is an opportunity to rethink the energy networks in complex ecosystem.

The Morocco experienced a remarkable evolution in exploitation of renewable energy (Sun, Beach , Wind). Indeed, Morocco is implementing large scale solar energy project through the Moroccan Agency for Solar Energy (MASE) and the Industrial consortium and many separate project for wing energy. Implementing such project in Morocco will benefit its initiatives and will enable the development of engineers who will be able to address these challenging issues with global perspective. In many prospects to exploit natural resources for production of energy and a better management of distribution and consumption, Morocco will become a leader energy producers. Therefore, Smart Grid technology and applications, becomes an absolute necessity for success in this challenge.

III. APPLICATION AND MOROCCO CASE STUDY

Electricity supply in Morocco is strongly dominated by conventional electricity generation and imports from Spain gain major importance to cover the demand successfully. The electricity consumption grew substantially in the last decade, while the expansion of installed capacity was at the edge to keep pace. Very ambitious expansion scenarios for the power generation capacity have to be considered so that peak demand and a desirable security margin can be guaranteed by domestic resources until 2020.

Production: Electricity is produced by either ONE, independent producers, auto producers or imports. In 2009 the four sectors accounted for 33.7%, 53.5%, 0.2% and 19.3% of the total electricity respectively. ONE produces coal power, hydropower and electricity from fuel oil and diesel generators all over Morocco. The new plants are listed in Table 1 sorted according to fuel type. At the end of 2011 all conventional projects scheduled until this date have been built. However, about 600 MW of planned wind farms are delayed or have not been installed at all.

A. Sensors control and prevention system of energy production and consumption

Energy demand in Morocco is expected to increase steadily between 5-7% per year until 2020. Is highly dependent on energy imports, Morocco will face considerable energy costs and the growth of electricity consumption. Thus, emphasis should be placed on the transmission and distribution which refers to the process of delivering electric energy from the high voltage grid to consumers and it includes electric lines and transformers (substations) that take power from the high voltage grid and progressively step down the voltage, As well as line management systems that improve efficiency, such as Smart MicroGrid. These are responsible for delivering electric power—no matter the generation source, be it solar, gas, oil, wind or otherwise—using digital technology that allows for a two-way communication between the utility and its customers.

As previously described, the distributed database required to operate the multi-agent system, on which is entirely based the design of our project for the management of energy flow between consumers and the distribution network at which they are connected requires a continuous and real-time data on consumption and production at each network node represented by one or several consumers whose behavior is identical energy needs, and delivery points that represent the primary electric energy sources.

In the case of a Smart Micro Grid, it’s of course about a specific type of grids whose main characteristics are the voltage level: 20KV and 22kV for medium-voltage MV, 380V for low-voltage network LV, typology and network structure. We distinguish then loop networks or antenna ones, aerial or underground, and other mixed cases. Nowadays, this type of grid is the necessary distribution network to ensure the power supply of a neighborhood or even of a big city or a province.

To transmit electric energy efficiently, medium voltages are used. It is then converted to low-voltage electricity (MV/LV) through substations (transformers), that are characterized by its nominal power expressed in kVA and the number of departures LV . Consumers are connected either directly to the MV grid for power demand greater than 80 KVA or on the BT network for a power demand less than or equal to 80 KVA, according to regulations imposed by the electric energy distributors (ONE is The only company responsible and working as transmission system operator TSO)

The electric energy consumed on LV grids, often by households is accounted for using electricity meter. An electricity mxxeter is thus a device that measures the amount of electxxxxxric energy consumed. it is installed at the consumer and it is made on the basis of electromechanical technology (counter disc). Electricity meters are typically calibrated in billing units, the most common one being the kilowatt hour [kWh]. Furthermore the production costs can be compared with end consumer prices in the market which are fixed by decree of the Moroccan Prime Minister. Periodic readings of electric meters establish billing cycles and energy used during a cycle (The price per KWh is more expensive when going from one slice to another lower top). But in rural areas, an electronic prepaid card is inserted in the PERG for consumers who are geographically dispersed where the record of index counters presents a very expensive cost for the distributor. The consumer then buys its energy even before consumption. Here, a single tariff is applied.

For customers connected to the MV network, their consumption is recorded using a Smart meters which provided much more information of the electric energy consumption. Smart meters are the next generation of electricity meters and the difference compared to the old meters is that they are able to transmit and receive data. Smart metering is one way to help customers understand their electricity consumption and help them to save energy.

Through a quick feedback and monthly bills, with statistics over the electricity used, the customers will get a better understanding of their electricity consumption. Customers should be able to analyze and optimize the electric energy consumed per time: peak hour, peak hour and peak hour. It also gives the maximum power, the average power factor and minimum, the cumulative active energy in kWh import / export, the accumulated reactive energy in kvarh import / export. These Smart meters usually have a network interface which allows for the remote index reading. This option is not yet operational due to insufficiency of telecommunications infrastructure in distributors. The supplier or distribution system operators will profit from smart metering since they do not need to dispose so much expensive peak power. Through load variable tariff customers can profit as well, since they can optimize their electricity consumption against the given prices. costs are not the same for all customers MT. This depends on the nature of the activity performed by the consumer, whether a small farmer or industry.

From the above, the smart Micro Grid is identified as two interlocking grids: LV network where consumption is linked to household habits that represent the majority of consumers connected to the grid, and a major source of MV network supply the LV network, where consumers directly connected network, drivers often have a Generating Station with high powers.

The necessary data acquisition for the operation of laour automated system for managing production and demand will be carried out in three steps to a better optimization of investment required for the installation of smart meters that communicates the real-time information through communication and data transmission infrastructure the control center hosting the application object of our project:

- In terms of MV/LV stations (customer or distributor) whose number is less important than LV customers. The distribution Stations MV/LV for to supply LV grid that is mainly supplied for households. Because they have a uniform behavior towards energy needs, energy absorbed by the electric MV / LV distribution, reflects clearly this behavior. For MV / LV customer, the consumption depends on the nature of the economic activity. Several scientific models are exploited for the prediction of consumption.
- In terms of LV customers who have their own means of energy production (solar, wind, etc.), a way to manage the flow of energy flowing of this node.
- For each new subscription and renewal
- Generalization following a timetable which takes into accounts the available financial resources.

This intelligence, desired at the level of such meter has processing capabilities and control to be defined on the basis on discussing focusing on the introduction of the pacer distributor in consumer privacy to influence lifestyle which has a direct impact on energy consumption and maximum power consumption. Knowing that today most retailers are in the process of finalizing their regional centers of remote telecontrol that ensures continuous monitoring of the distribution and control of bodies cuts (breaker, switch) to ensure a better quality of service by:

- A development charge between different arteries forming the network to avoid overload drivers and reduce the voltage drop in the end.
- A quick recharge customers following incidents insulation faulty line section.

The system to perform must then be grafted onto the existing platform in order to exploit first the infrastructure already in place, namely the breaking components remotely controlled and communication means, and secondly the Human resources qualified for the management and distribution networks that can provide their expertise in the field.

I. General Applicative Context and Proposed Solution

A smart MicroGrid refers to a distribution network for electrical energy, starting from electricity generation to its transmission and storage with the ability to respond to dynamic changes in energy supply through co-generation and demand adjustments. At the scale of a small town, a MicroGrid is connected to the wide-area electrical grid that may be used for 'baseline' energy supply; or in the extreme case only as a storage system in a completely self-sufficient MicroGrid. Distributed generation, storage and intelligence are key components of a smart MicroGrid.

A typical scenario to consider is a customer implementing a renewable energy generator system that will be used to deliver electricity to its needs. Such a customer can draw more energy from the grid, store its energy, or send energy back to the smart grid. In other words, customers can buy, store, or sell energy. To make this scenario happen, the customer's system needs to communicate with the grid (by interacting through the meters) in order to get all necessary control information. The research question that we plan to answer in this proposal is how to design a wireless sensor network that will enable efficient and cost effective network communication between the renewable energy system and the meter. What is the efficiency software that response to requirement of the system? What is the technology that most suitable for such project. This project is shared into three parts:

To achieve our goal, first we need to develop a simulation platform for energy resources management of a MicroGrid Network to optimize and manage the distribution on demand. With the existence of several energetic resources and local production site by consumers, the system will automatically establish an efficient electricity distribution. In this project, we propose the use of the multi-agent technology. This choice is motivated by the functional ability of agents, and their self-adaptation to the environment (i.e. change the feature), and their ability to communicate with other agents and inter-site mobility will define and specify the real-time needs of each site according to its production capacity and consumption and that of its neighbors. The architecture of the operating system is based on a graph, where each node represents a site energy, which can be a customer support or a producer of energy.

In the second part, and to facilitate communication inter-agents and to optimize the time of data transfer between agents from different sites, and the ability to store the data on other sites, gives more flexibility in terms of Security, availability and overload the network. In this perspective the use of the principle of Distributed databases in the context of this project report a very suitable solution for our situation. Distributed databases offers many benefits: reduced costs, increased flexibility, and simplified access "on demand" to data with greater agility. Indeed, Distributed databases offers space and computing power to store the several centers, but also the possibility of analyzing the data, processing them and distribute them more efficiently and cost on any server based on availability and needs. The distributed databases effectively split the computational capabilities available, enabling more people easier access to more and more data. On the other hand, allows the prediction of risk in an electrical network model for information. Thanks to the distributed databases solution, we can easily migrate critical data on a data center and improve the response time of readjustment and equilibration of the distribution and consumption.

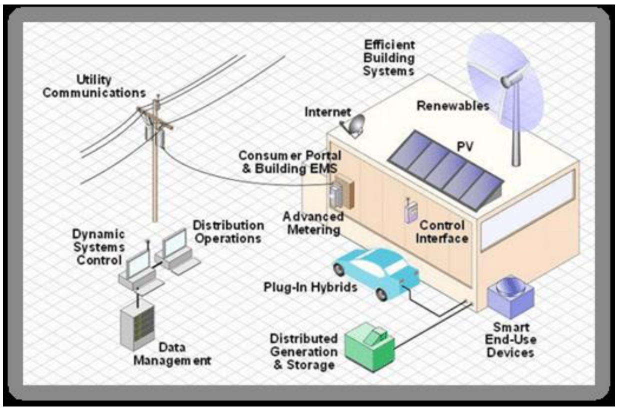


Figure 1. Smart Grid Features

In the last part, this project aims at controlling and adjusting automatically the consumption following the need of each customer at real time using remote control systems. The project starts by defining all parameters influence on the energy consumption for all components one related to others. Each parameter will be represented by a coordinator sensor to give local consummation information. The calculation of real-time needs of delivery or energy demand of each network element, based on the ratio of balancing consumption / production on the entire network. To achieve this scientific need, we are planning to use data mining technology. This is, a procedure to follow to use the data, whatever their forms, in order to extract knowledge. There are the following steps:

- Access and preparation of data, for processing at each site, stored in a structured (database, tabular files) or unstructured (text, image, etc.).;
- Using data mining techniques derived from statistical or machine learning;
- Evaluate and validate the extracted knowledge on the report of balancing consumption / production.
- Deployment of knowledge to use and effective decision-making readjustment of the distribution.

IV. General Overview of Related Research

This section presents the details of our research axis. We provide an overview of WSN, SMA and Data processing. We highlight what makes them different from traditional data integration methods and why they have enabled the solution of previously unsolved problems. We discuss four research problems that help solving data integration for smart grid system. We list problems in what we consider an increasing level of difficulty. For each research problem, we give a formal description, the main research issues we have identified as of now and a proposed research plan. After research issues and solutions are presented, we explain how the proposed research will be developed for correctness, how architecture will be evaluated for accuracy/validity and how our method will be evaluated for efficiency. This section explains the application of WSN, MAS, Data integration and Data processing on the Smart Grid, where data sets are large, high dimensional or have rich information content (numbers, strings, data).

A. Wireless Sensors Network

First, we will adequate the information gathered by the transducers of the physical sensors to a useful format for the developed device. Generally, wireless devices have quite high average power consumption. Thus, in our development we will take into account several issues to save energy and reduce the power consumption as much as possible. The first issue taken into account is to disable the unused parts of the device while they are not being used, which reduces the power consumption significantly. The other issue is the protocol used for communication. We have to design an energy efficient protocol in order to save energy when the information must be transmitted between the electronic low power device and the tablet PC or the mobile phone. Finally, we will design the appropriate algorithm for the behavior of the nodes, that is, the algorithm will decide when de node will be in sleep mode, where there is very low power consumption, and when the node must be active in order to transmit or to receive the information. Moreover, we will add fault tolerance and security to the network. It will allow us to optimize the implementation of a modular sensor node that will be used for different type of applications, with high bitrates. After the device deployment we will deploy new Linux-based operative system that allows gathering data from the physical sensor interfaces and forward them to the Bluetooth interface to be received by the tablet PC and the mobile phone

B. Multi Agents System and simulation

Our project concerns the design and development of a system for Intelligent Decision Support to discover the need for balancing the energy ratio of the two factors consumption and production. And to make decisions looking distribution of energy based on the cooperation of a sensor network simulated by autonomous agents. It involves developing a new system with intelligent autonomous components to exploit the capabilities (or services) of sensors. In general, the expected features are, among others,

Our project concerns the design and development of a system for Intelligent Decision Support to discover the need for balancing the energy ratio of the two factors consumption and production. And to make decisions looking distribution of energy based on the cooperation of a sensor network simulated by autonomous agents. It involves developing a new system with intelligent autonomous components to exploit the capabilities (or services) of sensors. In general, the expected features are, among others,

- Permit an entity to describe his skills.
- Automatic detection and classification, possibly with multiple new skills to exploit them.
- Authority to give optimal decision and forecasts for the pretreatment of critical situations
- Treatment transparent and cooperative delegated services.
- Implementation and achievement of the testes in different application domains.

To do this, the system can cooperate within the framework of a federation, and provide appropriate responses. For example, before or during the search of suitable energy sources to meet a critical need, the other remote systems with available resources and services can be combined with those of the local system to optimize the distribution in a manner transparent. This feature relies on the classification, localization and deployment of powers established by several heterogeneous distributed systems.

C. Data Integration

As like as Smart Grid environment, in the distributed environment where a query involves across several heterogeneous sources, communication cost must be taken into consideration. In his paper we describe two query optimization approaches using dynamic programming technique for a given set of integrated heterogeneous sources. The primary objective of the optimization is to minimize the total processing time including load processing, request rewriting and communication costs, to facilitate communication inter-sites and to optimize the time of data transfer from different sites. Moreover, the ability to store the data on center site gives more flexibility in terms of Security/Safety and overloading the network. In contrast to optimizers which consider a restricted search space, the proposed optimizer searches the subsets of sources and independency relationship which may be deep laniary or bushy trees. Especially the execution de query can be started traversal anywhere over any subset and not only from a specific one.

The main problem is to maintain a distributed data warehouse, consisting of multiple local data warehouses (sites) adjacent to the collection points, together with a coordinator. This coordinator uses ontologies to explicit the semantic of sources. The heterogeneity is caused by the diversity of smart grids that may have various constructors, models, technologies, etc. Once the distributed data warehouse constructed, we need to classify the data to extract the profiles of consumers. The development of adapted algorithms represents a crucial issue that has to be described. The basic idea of such algorithms is to translates a set of sources into distributed distinct subsets and generates distributed warehouses, with the following concept: (i) each generated data warehouse performing some computation and communicating the query result to the coordinator, and (ii) the coordinator synchronizing the results and (possibly) communicating with the warehouses. The semantics of the sub queries generated by system ensure that the amount of data that has to be shipped between warehouses is independent of the size of the underlying data at the sites.

The solution allows for a wide variety of optimizations that are easily expressed in the interrogation and thus readily integrated into the query optimizer. The optimization algorithm included in our prototype contributes both to the minimization of synchronization traffic and the optimization of the data processing at the local sites. Significant features of this approach are the ability to perform both distribution-dependent and distribution in dependent optimizations that reduce the data transferred and the number of evaluation rounds.

D. Data Integration and data Processing

The basic idea of this algorithm is: data in the network is transmitted as the entire relationship or a fragment from source to others, which is obviously a redundant way. When a relationship transferred to another venue, not every data is involved in connection operation or useful. Therefore, the data is not involved in the connection or useless data needs not to be transmitted circularly in the network. The basic principle of this optimization strategy is to use semi-connection operation to only transmit the data involved in the connection in the network as far as possible.

In the perspectives of this project we address the following research areas:

- Hybrid integration of data sources:
- Recommendation of energy resources based on consumer profiles
- Inter-agent negotiation
- Invoice generation based on the usage of energy

E. Data Processing and analyzing

The challenge is to integrate the large amount of data from customer demand with the data on power grid performance. The data from customers is noisy and rich in information. Data-analysis applications have to filter the data and find trends in close to real time. Utilities plan to use such trend information to make decisions on power grid operation. The goal will be to have software operate the power grid in accordance with such trends.

While the needs of large utilities are driving development, second tier power grid operators also have to implement smart grid technologies. The solutions they choose are of particular interest to midsize businesses because these smaller utilities are often of comparable size. Such solutions may offer these businesses expanded data processing and analyzing at reasonable cost. Access to large amounts of data: Customer files, market analyses, and internal sources could yield more useful information with expanded and more powerful analytics. As smart grid development pushes the upper limits of data management, the middle capabilities expand as well. That could give midsize businesses cost-effective access to the technology they need to squeeze more information out of their data.

V. FUNCTIONAL ARCHITECTURE

In this part and first, we start with the description of the functional architecture of the system. This architecture is based on the concept of directed graph defined as follows: Each node represents a geographical site brings together a set of resources in the production of energy and consumer group. The arcs among nodes (sites) represents the amount of energy lost during transfer from one site to another. In his considered at the same site there is no transfer of energy between production stations.

For the organization of the functional architecture we define the two possibilities of the following links:

Site-to-Site: This link means that energy production plant can power another via a temporary transfer

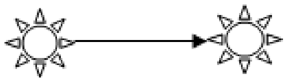


Figure 2. Site-to-Site

Site-to-Consumer: This link means that a customer uses energy generated by a production site.

Figure 3. Figure 1Site-to- Consumer

To simplify the system we define the various components, into five categories:

- Base stations of energy production that can generate the energy: Distribution substations, wind turbines or / and solar panels.
- Local generation/consumption of energy, which can be: House, Laboratory, Research Centre, etc ...
- Mobile Generation/consumption, which can be: vehicle, mobile emergency units
- The static Consumer of the energy.
- The mobile Consumer of the energy.

Since the amount produced and consumed by each site depends on producers and consumers in a given site and exchanges with other sites, and with the consideration of mobile generators and consumers we must highlights the reorganization phase sites in dynamically moving a consumer or a generator from one site to another.

To ensure the balancing management and distribution of energy between the sites, each site is associated a database for storage of the quantities produced by the generator and the quantities consumed by the customers of this site. Data from this these databases will enable us to make decisions on prevention and global production and consumption in the networks to effectively manage energy transfers between sites.

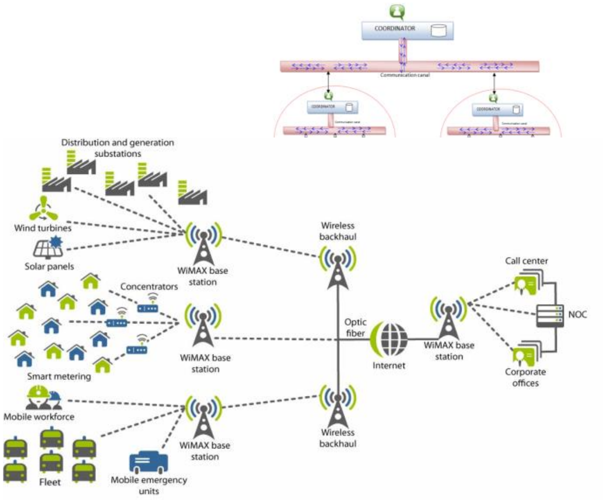


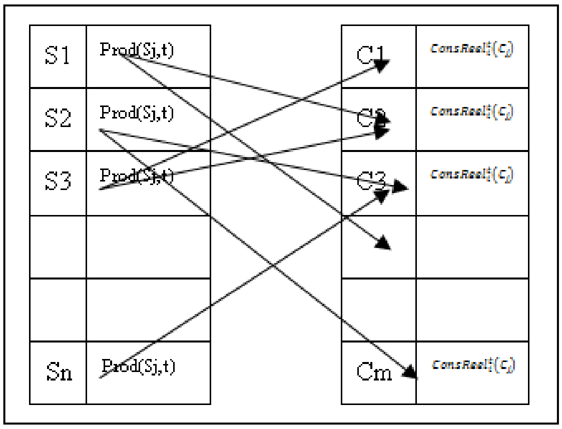
Figure 4. Proposed Solution based on collection of local data in data centre where the coordinator communicates with others via distributed agents.

Thereafter we will define the data model to use to perform the algorithms presented above. The system we propose is divided into two Levels: inter-Nœud and intra-Noeuds.

A. *Inter-node architecture.*

Each node Ni is characterized by:

- Production capacity of each energy resource at a given Sj of this node: Prod(Sj,t)
- Actual energy consumption of a client at a given time: $ConsReel_i^t(C_j)$
- The amount of energy transmitted by a source Sk to a customer of a node Ni at time t: . $Quantite_i^t(S_k, C_j)$
- Geo- localization Lj(x,y).
- The nature of the Nat sources Nat(Pi)



We define the following variables:

- Whose total amount transmitted to customers Cj at time t represented by a node Ni is:

$$TotaQuantity_i^t(C_j) = \sum_k Quantity_i^t(S_k, C_j)$$

- The total amount of production of a site represented by a node Ni:

$$Capacity(N_i) = \sum_j Prod_i^t(S_j)$$

- Total consumption of a site represented by a node Ni

$$ConsTot(N_i) = \sum_j Cons_i^t(C_j)$$

- The quantity of energy lost at time t by a customer Cj is:

$$LostQuantity_i^t(C_j) = TotalQuantity_i^t(C_j) - ConsReel_i^t(C_j)$$

With the condition:

$$0 < LostQuantity_i^t(C_j) < \beta$$

With β is the tolerance allowed for the loss of energy when demand for end customers satisfaction.

B. *Intra-Nodes Architecture.*

In this section we present the graph representing the electricity network in which each node Ni (Pi, Ci, Ri) is a region that includes the energy Pi production resources, consumer list that use the resources of this area Ci lists and constraints to meet Ri.

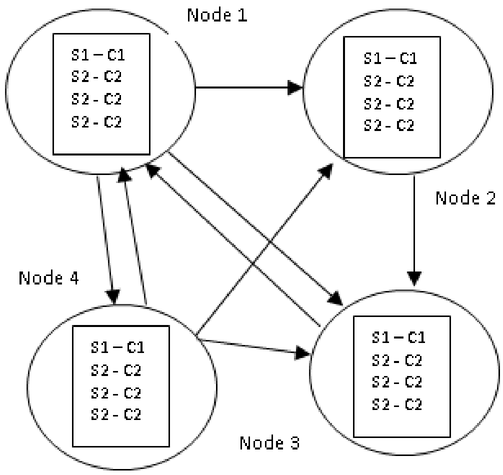


Figure 5. Iner-Node Architecture

Whether:

$$Arc(i,j) = transmittedQuantity(N_i) - ReceivedQantity(N_i)$$

With

$transmittedQuantity(N_i, N_j)$ represents the amount of energy transmitted from the site Si to the site Sj and $ReceivedQantity(N_i, N_j)$ represents the quantity received by the site Sj transmitted by Si.

We must therefore ensure balance between production and consumption and energy transfer between the S_j site and S_i as follows:

$$Balancing\ (Si) = Prodi(S_i, t) + TotaQuantity\ (Si) - \sum transmittedQuantity(Si, Sj)$$

We seek to develop an algorithm that minimizes the values Arct(i,j) and maximize $Balancing\ (Si)$ for all i and j. This means to minimize the energy lost during transfer or balancing process among the sites represented by the graph and takes a right distribution of energy between the sites.

VI. SOURCES CLASSIFICATION AND CONSTRAINTS SATISFACTION

Thereafter we propose a solution for the distribution and classification of sources and end customers at all sites (Micro-Grid). That means, the construction of nodes of the graphs to consolidate energy resources and consumers of the same category according to two criteria: Geographic and satisfaction rate. Then developing a distribution algorithm and balancing of energy between the sites represented by the graph shown in the previous section.

A. Algorithm : Classification within Micro-Grid

Energy sources classification algorithm and consumers is mainly based on consumers who share the same energy resources with the objective of minimizing the energy transfer between the sites (inter-site).

For the definition of all sites (Micro-Grid) we follow the following steps:

1. Selection of centers for gathering geographically close energy resources or when the distance less than Dis (Si) for each center Ci. The choice of the threshold depends on the region.

$$Consomateurs\ (S_i) = \{C_j \ / \ Quantite_i(S_i, C_j) \neq 0\}$$

2. Appropriation of the consumers fed by the same source of energy resources even micro-Grid.

$$Consomateur\ (S_i) = \{C_j \ / \ Quantite_i(S_i, C_j) \neq 0\}$$

3. For consumers fed by one or more Micro Grid, they are affected each site whose difference between the total consumption and the total cross-site production and the maximum possible.

$$Consomateur\ (S_i) = \{C_j \ / \ Quantite_i(S_i, C_j) \neq 0\}$$

VII. CONCLUSION

In this paper we proposed a solution to ensure the balancing of distribution and consumption of energy between micro-grid groups. This solution will minimize the loss of energy during the transfer process and to consumption of energy.

The solution is based on the real-time study of consumer needs and distributed generation on all energy site

REFERENCES

[1] Pepermans G, Driesen J, Haeseldonckx et al (2005) Distributed generation: definition, benefits and issues. Energy Policy 33:787–798

[2] Molderink A, Bakker V, Bosman M et al(2010) Management and control of domestic smart grid technology. IEEE Trans. Smart Grid 1(2):109–119

[3] Carrasco J, Franquelo L, Bialasiewicz J et al (2006) Power electronic systems for the grid integration of renewable energy sources: a survey. IEEE Trans. Industrial Electronics 53(4):1002–1016

[4] J. J. Justo, F. Mwasilu, J. Lee, and J.-W. Jung, "AC-microgrids versus DC-microgrids with distributed energy resources: A review," Renewable and Sustainable Energy Reviews, vol. 24, pp. 387–405, Aug 2013.

[5] J. Guerrero, M. Chandorkar, T. Lee, and P. Loh, "Advanced control architectures for intelligent microgrids–part I: Decentralized and hierarchical control," IEEE Transactions on Industrial Electronics, vol. 60, no. 4, pp. 1254–1262, Apr 2013.

[6] J. Guerrero, P. C. Loh, T.-L. Lee, and M. Chandorkar, "Advanced control architectures for intelligent microgrids – part II: Power quality, energy storage, and AC/DC microgrids," IEEE Transactions on Industrial Electronics, vol. 60, no. 4, pp. 1263–1270, Nov 2012.

[7] SolarRay, "Grid-tie package systems without batteries," http://www.solarray.com/CompletePackages/Grid-Tie-No-Batteries T.php, posted on: 2012.

[8] D. Westermann and M. Kratz, "A real-time development platform for the next generation of power system control functions," IEEE Transactions on Industrial Electronics, vol. 57, no. 4, pp. 1159–1166, April 2010.

[9] N. C. Ekneligoda and W. W. Weaver, "A game theoretic bus selection method for loads in multibus DC power systems," IEEE Transactions on Industrial Electronics, vol. 61, no. 4, pp. 1669–1678, Apr 2014.

[10] T. Bas¸ar and G. L. Olsder, Dynamic Noncooperative Game Theory. Philadelphia, PA: SIAM Series in Classics in Applied Mathematics, Jan. 1999.

[11] J. V´asquez, J. Guerrero, J. Miret, M. Castilla, and L. de Vicu˜na, "Hierarchical control of intelligent microgrids," IEEE Industrial Electronics Magazine, vol. 4, no. 4, pp. 23–29, Dec 2010.

[12] J. Guerrero, J. Vasquez, J. Matas, L. de Vicu˜na, and M. Castilla, "Hierarchical control of droop-controlled ac and dc microgrids – A general approach toward standardization," IEEE Transactions on Industrial Electronics, vol. 58, no. 1, pp. 158–172, Jan 2011.

[13] J. Guerrero, J. V´asquez, J. Matas, M. Castilla, and L. de Vicu˜na, "Control strategy for flexible microgrid based on parallel line-interactive ups systems," IEEE Transactions on Industrial Electronics, vol. 56, no. 3, pp. 726–736, March 2009.

[14] C. Hill, M. Such, D. Chen, J. Gonzalez, and W. Grady, "Battery energy storage for enabling integration of distributed solar power generation," IEEE Transactions on Smart Grid, vol. 3, no. 2, pp. 850–857, June 2012.

[15] Y. Liu, C. Yuen, S. Huang, N. U. Hassan, X. Wang, and S. Xie, "Peakto-average ratio constrained demand-side management with consumer's preference in residential smart grid," IEEE Journal of Selected Topics in Signal Processing, vol. PP, no. 99, pp. 1–14, Jun 2014.

[16] N. U. Hassan, M. A. Pasha, C. Yuen, S. Huang, and X. Wang, "Impact of scheduling flexibility on demand profile flatness and user inconvenience in residential smart grid system," Energies, vol. 6, no. 12, pp. 6608–6635, Dec 2013.

[17] I. Balaguer, Q. Lei, S. Yang, U. Supatti, and F. Z. Peng, "Control for grid-connected and intentional islanding operations of distributed power generation," IEEE Transactions on Industrial Electronics, vol. 58, no. 1, pp. 147–157, Jan 2011.

[18] Y. Liu, N. Hassan, S. Huang, and C. Yuen, "Electricity cost minimization for a residential smart grid with distributed generation and bidirectional power transactions," in IEEE PES Innovative Smart Grid Technologies (ISGT), Washington, DC, Feb 2013, pp. 1–6.

[19] D. Zhang, N. Shah, and L. G. Papageorgiou, "Efficient energy consumption and operation management in a smart building with microgrid," Energy Conversion and Management, vol. 74, pp. 209–222, Oct 2013.

[20] H. Kanchev, D. Lu, F. Colas, V. Lazarov, and B. Francois, "Energy management and operational planning of a microgrid with a pv-based

active generator for smart grid applications," IEEE Transactions on Industrial Electronics, vol. 58, no. 10, pp. 4583–4592, Oct 2011.

[21] Raab A, Ferdowsi M, Karfopoulos E et al (2011) Virtual power plant control concepts with electric vehicles. In Proc. 16th International Conference on Intelligent System Applications to Power Systems. IEEE, New York, pp 1–6

[22] Jansen B, Binding C, Sundstrom O, Gantenbein D (2010) Architecture and communication of an electric vehicle virtual power plant. In: Proc. SmartGridComm'10. IEEE, New York, pp 149–154

[23] Xiangjiaba–Shanghai HVDC system. [online] Available: http://en.wikipedia.org/wiki/ -Xiangjiaba%E2%80%93Shanghai HVDC system. Accessed March 2015

[24] Gemmell B, Dorn J, Retzmann D et al (2008) Prospects of multilevel VSC technologies for power transmission. In: Proc. Transmission and Distribution Conference and Exposition'08. IEEE/PES, USA,pp116

[25] Li F, Qiao W, Sun H et al (2010) Smart transmission grid: Vision and framework. IEEE Trans. Smart Grid 1(2):168–177

[26] International Energy Agency (2002) Distributed generation in liberalised electricity ma -rkets. [online] Available:http://gasunie.eldoc.ub.rug.nl/FILES/root/2002/3125958/31 -25958.pdf. Accessed Mar 2015

[27] Coster EJ, Myrzik M, Kruimer B et al (2011) Integration issues of distributed generation in distribution grids. Proceedings of the IEEE 99(1):28–39

[28] Pudjianto D, Ramsay C, Strbac G (2007) Virtual power plant and system integration of distributed energy resources. IET Renew Power Gener 1(1):10–16

[29] Ruiz N, Cobelo I, Oyarzabal J (2009) A Direct load control model for virtual power plant management. IEEE Trans. Power Systems 24(2):959–966

[30] Lombardi P, Powalko M, Rudion K (2009) Optimal operation of a virtual power plant. In: Proc. Power & Energy Society General Meeting. IEEE, New York, pp 1–6.