Economic implications of microgrid operation dispatching using Cuckoo Search Algorithm

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Abstract: As a method for analyzing fractals taking the source-network-load-storage into consideration, this slide will show the improved cuckoo search algorithm, inspired by some cuckoo species by laying their eggs in birds' nests host from other species. This improved algorithm can be applied for various optimization problems, but in this paper it was applied only for coordinated energy management based on demand in distribution networks. For short, the algorithm starts by initializing the data and the surplus sale conditions, each hour with sale is a nest and all the PV powers are a population. Each egg is a load-storage-production-surplus profile. This profile is randomly analyzed according to the optimal cost between sale or purchase or storage. The result is an ordering of the intervals of the day at a optimum microgrid operating cost. This advance algorithm has been integrated in Siemens PLC and a logic diagram is developed in this paper.

Key-Words: Cuckoo Search Algorithm, operation cost, microgrid, financial analysis

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1 Introduction

One of the European Union's strategic goals is the development of a new energy system that incorporates climate change policy. The European Commission's for Energy Development for 2050 [1], which was announced more than ten years ago, set goals for promoting the transition to a more reliable, durable, and carbon-free energy system. In order to transition to future intelligent grids (future Smart Grids) [2]-[5], remodeling will focus on integrating massive amounts of renewable energy sources, storage devices, and, in terms of workload, a larger proportion of active and controllable tasks. It will also integrate all necessary intelligent management functions.

Modern society relies on a highly reliable electricity supply system [6]-[9]. The current problems regarding the availability of primary energy, the aging of the transmission and distribution infrastructure of electricity networks, the need to install new sources of production (such as renewable sources) and the sale of electricity through wholesale markets constitute a challenge for system operators in terms of security, safety and quality [10]-[15]. That is why important investments are needed for the development and modernization of the electrical infrastructure, and the most effective way to respond to social demands will be the incorporation of innovative solutions, technologies and network architectures.

Implementing three key goals for energy generation—transition to intermittent renewable sources, distribution network connectivity, and adoption of advanced ICT solutions [16]-[19]for decentralized energy management—has resulted in evolution in the design of intelligent energy transmission systems.

It is important to emphasize that all of these goals can be connected to the idea of a multi-microgrid.

In addition to the classic infrastructure of a power grid, which includes lines, transformers, protection and automation systems, a microgrid includes smart consumers, distributed generators, advanced fault detection systems, intelligent switching equipment, an advanced measurement infrastructure, backup power supply, as well as a monitoring and control system that includes IT products and with the help of which the following objectives can be achieved:

- Isolation of the microgrid in the event of a blackout in the SEN;
- Optimizing the cost of electricity, compared to the one obtained on the electricity market, using own resources, both electric generators and storage sources, as well as active consumers;
- Improving the reliability and quality of electricity through the possibility of reconfiguring the electricity network;

- Increasing efficiency and reducing emissions of polluting substances by integrating renewable energy sources, such as photovoltaic panels, micro-hydro plants, wind turbines;

2 Related work

A microgrid [22]-[25] can be developed within an electric distribution network (RED), medium voltage or low voltage.mOperators of microgrids will run more microgrids because of the smaller size.

The multi-microgrid concept is an emerging architecture for a medium-voltage (MV) power generation system made up of more active low-voltage (LV) active wires, also known as micro-reels, distributed generation units with controllable tasks, and storage devices.

Distribution networks begin to transform from passive networks to active networks in the sense that decision-making and control are distributed, and power flows bidirectionally [25]-[29]. This type of networks with the participation of distributed generation, renewable energy sources and storage devices, offers solutions for new types of equipment and services, each of which is required to comply with common standards and protocols.

The classification of consumers and their control within a microgrid can also contribute to flattening the load curve either in isolated mode or in grid-connected mode.

A commercial or industrial microgrid can become isolated when the quality of electricity from the main grid does not meet the requirements and can even affect the quality of the electricity provided by the microgrid [30]-[33]. The independent operation from the main grid of the commercial/industrial microgrid can be planned, e.g., at peak load when the price of electricity absorbed from the main grid is high.

A microgrid can also supply a small residential consumer, i.e. a group of city houses. The residential microgrid ensures a convenient and efficient electricity supply system that is customized according to the demands of consumers and the distributed generators used. The generation of solar panels and microturbines in cogeneration constitute attractive distributed sources for residential applications and commercial buildings.

3 Advanced load control

Depending on the geographical characteristics of a remote area and the availability of resources of various types such as: microturbines, windmills, photovoltaic cells and gas turbines with low emissions, can be used. A major difference in the remote microgrid model [34]-[38] is that the production must be sized to serve the entire load with an adequate level of reserve capacity. In addition, the dispersion of the load and the big differences between the minimum and maximum load of the microgrid make the selection technology, the size of the DER a competitive thing. The following methods are suggested to realize the short-term or long-term energy balance of withdrawn microgrids designed to overcome power fluctuations introduced by intermittent generation and variable load:

- Advanced power sharing and engagement of units through a set of multiple generation sources to select the right combination of DER as a function of load variation.
- Using the optimal size of energy units
- Advanced load control

The management and control of a multi-microgrid is provided by the hierarchical control architecture. Each microgrid, managed by the micro-grid central controller (MGCC), communicates with the distribution management system (DMS) designed to monitor and control the distribution network. The implementation of a multi-microgrid concept therefore implies the technical and commercial integration of several micro-grids with upstream distribution management systems and with the operation of decentralized energy markets and ancillary services.

One of the best-known microgrid pilot centers is the internal network at the Illinois Institute of Technology (IIT), Chicago-USA. For this project IIT benefited from a grant worth $7 million in 2005 from the DoE; another $5 million was secured from own funds and from private companies.

The project was based on 3 components:

- reliability (high degree of continuity in the supply of electricity to consumers)
- own production (use of own sources from IIT
- integration of new renewable sources) and reduction of electricity consumption.

Interconnection methods and technologies:

- directly by means of an interconnection switch
- by means of static switches
- using a power electronics based interface

a) Interconnection switch.
This solution is simple and cheap. The actuation mode is slow, requiring between 3 and 6 periods to achieve complete disconnection. The electrical characteristics present on both sides of the switch must match, making the operation of the microgrid closely related to the operation characteristics of the main grid. Thus, the use of the interconnection switch requires the microsystem to have at least one AC distribution system installed. to respect the characteristics of the electrical network. The flow of power through the common connection point cannot be controlled.

b) Static switches.
In general, the construction of these types of switches is based on the use of semiconductor rectifiers in an anti-parallel configuration in order to allow bidirectional power flow. Silicon Controlled Rectifiers (SCR - "Silicon Controlled Rectifier") are semiconductor devices that work like an electrically controlled switch. These devices are more expensive and much more complex in terms of operation than classic switches. Conventional circuit breakers are still commonly used with the aim of achieving complete galvanic isolation. A Bypass switch is introduced in the circuit with maintenance-related functions. Semiconductor interrupt devices are reliable and can be used for a high number of on/off operations. They act much faster than conventional switches (1/2 - 1 cycle less). Sometimes insulated gate bipolar transistor (IGBT) systems can be used as an alternative, as they tend to be faster than SCR systems. Power transfer cannot be controlled in this situation either. Conduction losses may occur in this equipment.

c) Power electronics
This approach is the most expensive but also the most flexible of all. First, it allows electrical systems located on both sides of the connection to operate with completely different characteristics. Active and reactive power circulation can be controlled. The connection and disconnection response times are similar to those provided by static switches, although in this case the response speed also depends on other parameters, such as dynamic performance (provided by the control system, network topology and storage system characteristics). However, in many cases it is necessary to install a circuit breaker on the network side in order to effectively physically separate the microgrid from the main network. Also, the presence of technology based on power electronics leads to the appearance of energy losses at the time of operation.

4 Cuckoo Algorithm

As a method for analyzing fractals taking the source-network-load-storage into consideration, this paper will analyze improved cuckoo search algorithm.
However, in the conditions where the market would be regulated for each fractal, such a concept would be based on a standard price of the cluster and meeting local consumption of new energy. This cost is equal regardless of the time at which power dispatching is done, because a first condition is that a microgrid cannot buy from another microgrid and sell in the network at the same time.
The result of the algorithm searches in multi-microgrids demands or storage to respond to the market cost and thus the demand with the offer in the market was optimized.

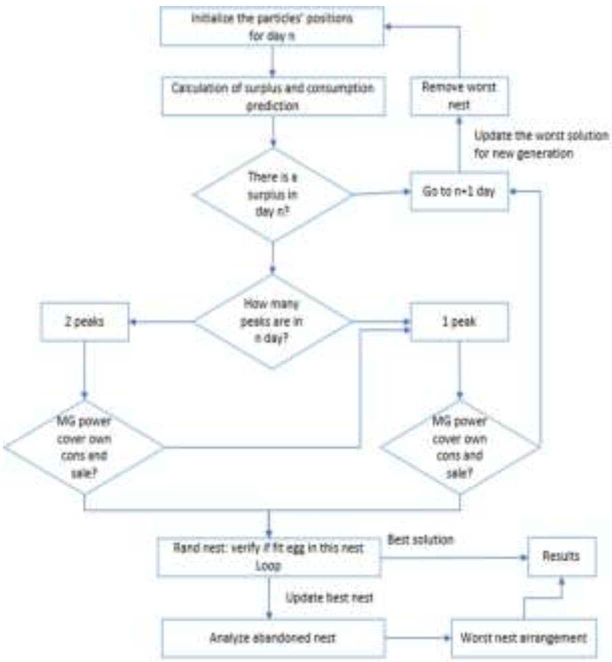

Figure 2. Cuckoo Flow Chart

A microgrid, through its control system, must ensure all or a subset of functions (for example: energy supply, participation in the energy market, black-start, provisions for auxiliary services, etc.) [39], [40].
The dynamic of proposed architecture can respond to the cost requirements of the market and was analyzed [41].

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5 Develop CS in microgrid PLC

A decentralized system can be applied with difficulty because coordination problems can arise between local systems, due to the large distances between them. A minimum level of coordination between the different control systems is required [42], and this cannot be ensured using only locally measured variables.

TIA Portal (Totally Integrated Automation Portal) is a software developed by Siemens for the programming of Siemens Step series PLC's (S7-1200, S7-1500, S7-300, and S7-400 families), which integrates multiple development tools for automation, such as: Simatic Step 7, Simatic WinCC, and Sinamics Starter. There is also an integrated simulator (PLCSIM), with which the user can test their code by randomly giving values to tags, values which can be modified by the user via Force tables to resemble a certain scenario more closely.

However, in order to simulate an actual PLC, a more complex simulator can be used along TIA Portal, called PLCSIM Advanced. This Simulator uses an instance of a PLC in order to run and gives a more realistic simulation.

After creating the project, the user can select from multiple programming languages: FBD (Function Block Diagram), SCL (Structured Control Language), LAD(Ladder), and the following communication protocols: Profibus, PROFINET, and AS-I (Actuator Sensor Interface). Additionally, communication modules are available for protocols like CANOpen and Modbus.

In the case of a FBD project, the program is comprised of predefined logic blocks are used in networks, blocks that usually act as logic gates: AND, OR, NOR etc. or timers (TON), counters (CTU), limits (IN RANGE), formulas (CALCULATE blocks) selectors (SEL) and many others. Languages like SCL and more closely resemble traditional programming languages, relying on conditional structures (if, if else statements) and loops (for, while).

Figure 3. PLC Network

Organization blocks are split into function, or FCs, function blocks, called FB and DBs: data blocks. The Organization Block1, called "main" plays an essential role in the programming of the PLC: it initializes all the other blocks and scans for their call to run, with the exception of Cyclic Interrupt blocks, which execute automatically on a preset time. The main block is used cyclically: at the end of the execution, it resumes the execution of the code in a process that runs indefinitely as long as the PLC is powered.

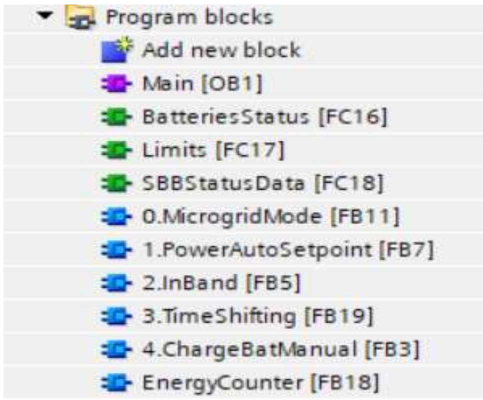

Figure 4. Program blocks

Real time monitoring of tags and variables is possible by selecting "Online" and entering either the "All tags" menu or the related networks, provided the PLC is connected and active, or if there is a running simulation

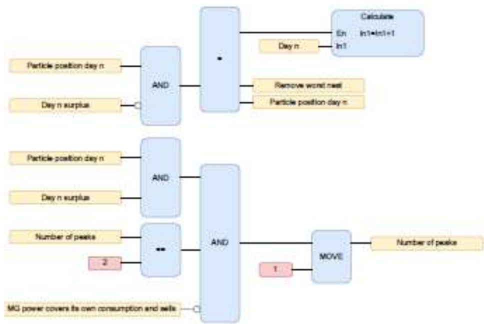

Figure 5. Initialization CS

Loading the program is also easier in TIA Portal: the user can select "Advanced download to device" and then load the program into the PLC after selecting the IP addresses and devices.

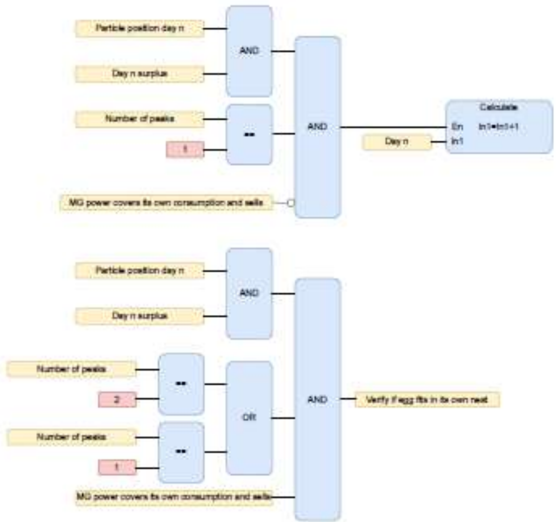

Figure 6. Random Cukoo Search Logic Diagram

6 Conclusion

The dynamic of proposed architecture can respond to the cost requirements of the market and was analyzed in terms of power systems operation based on a multi-microgrid optimization algorithm, which allows the exchange of the load for an efficient and safe operation.

As was mentioned, the optimization of energy production was done under the conditions of respect for robustness and adaptability.

In the future studies, there will be a more elaborate analysis on cost and microgrid on real data from a real microgrid source-network-load-storage and the optimization based on improved CS will be simulated and evaluated in the relevant environment, thus being an update to the work.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)
Msc. Ec. Andreea Ghinet dealt with the analysis of the hourly cost on peak and empty intervals. In accordance with the electrical market, an oprim bill was chosen and a financial analysis was identified for the dispatching and sales conditions.
PhDs. Eng. Teodora Mindra developed the Cuckoo Search Algorithm Flow Chart and integrated the scientific algorithm with optimal microgrid cost operation conditions, to increase resilience, efficiency and intercommunication with higher levels of control.
PhD. Eng. Luiza Ocheana took part in the development of the control logic of the microgrid solution: A controller developed by SIS SA using a redundant Siemens hardware platform will allow monitoring and control of system elements. Communication configuration of microgrid between the controller and the SCADA application is carried out through the IP protocol ISO S7 (ISO-on-TCP), that it uses the Ethernet infrastructure.
MsC. Eng. Emil Spiroiu developed a new diagram that will be integrated into the logic already developed, validated and running for 2 years, automatically. The diagrams were implemented in TIA Portal and based on them the forecast is made for the training of a real microgrid, developed in an office building: integrates solar panels with a totally installed power of 120 kW, two storage units of different capacities one with 40 kWh and other with 56 kWh.
Prof.PhD.Eng. Radu Dobrescu integrated the parts of research, specialized literature, concept of interest from R&D projects, future solutions, and a vision of creative development, multiplication of this microgrid control solution.

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Conflict of Interest
The authors have no conflicts of interest to declare that are relevant to the content of this article.

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