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Experimental Study for Intelligent Stability Control of Low Voltage Electrical Networks with PD-RES using Fuzzy Controllers

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Abstract

This paper proposes an engineering solution for stability control of the low voltage electrical networks with distributed power generation from renewable energy resources. First there are presented generally, the existing problems in this type of systems, capable to be solved with automation intelligent control. In the second part, the paper focuses over fuzzy controller design based on experimental monitored data and experts know how. The results of proposed software realized with Matlab® will be pointed out from the main objective point of view.

Key words: *fuzzy logic control (FLC), renewable energy resources (RES), distributed power generation*

Introduction

Renewable energy resources (RES) have represented in balance of energy of European Union (EU), in 2000, only 6%. The actual tendency in EU countries is the use of the renewable energy in order to reduce the contribution of conventional power stations fact that will reduce the gas emissions and will protect the environment and will increase the networks security [7], [8].

The major goal of this research work is to design and realize a fuzzy logic controller for the low voltage electrical networks with distributed power generation from renewable energy resources. [5], [9].

The paper is organized in three parts. Firstly, the low voltage electrical networks with distributed power generation from renewable energy resources will be presented and the existing problems capable to be solved with automation intelligent control systems will be pointed out. In the second part, the favourable arguments identified regarding the implementation of fuzzy controllers in real applications will be pointed out. Experimental monitored data will be valorised in a simulation designed and realized with Matlab®.

Low voltage electrical networks with distributed power generation

The classical structure of a distributed power system is reconfigured due to RES implementation. The architecture of a "green power" system is presented in the figure 1 [7]. The electrical power parameters (effective voltage, current, power factor) are monitored in real time in each node of the network and they are sent to the local network supervisor/central computer (PC) that will run the control support system [1]. Moreover, the environment parameters as solar radiations, temperature and wind speed could be measured.

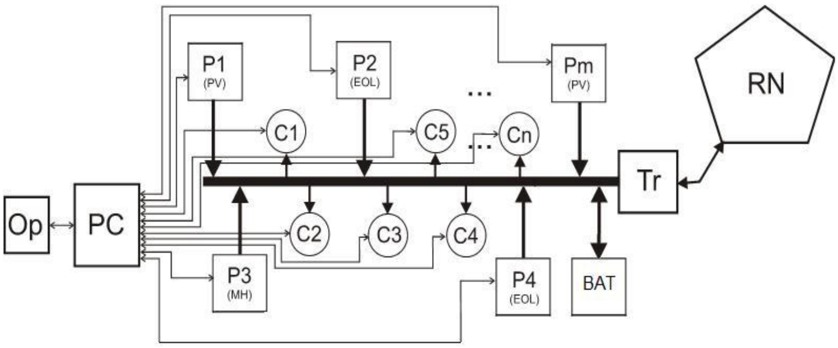


Fig. 1. Low voltage electrical networks with distributed power generation architecture.

Legend: P1, P2, ..., Pm – electrical energy generators (PV systems, wind turbine, micro hydro centrals, etc); ;C1, C2, ..., Cn – electrical energy consumers; PC – personal computer; OP – network operator; Tr – medium or low voltage transformer; RNE – national electricity network.

The elements of the network are: uncontrolled generators (those of renewable energy that have not dead times in which they don't generate the energy), controlled generators (diesel groups, fuel cells, battery invertors, groups of power stations, generators that are fuel consumers and work only in critical situations), controlled consumers (stocks, batteries, electrolyses), Uncontrolled consumers (all the housework and industrial consumers that can be only estimated and influenced by the variation of the electricity price) and main consumers (those of the first degree, i.e. 100% dispose).

The objectives to be achieved in this context are: the determination of the energetically under load or overload periods in the local networks, periods indicating the moments of decision taken in national power generation, the identification of the abnormal situations in generators or consumers functioning in view of the energy generation and transport process and in the main consumers feeding (local island type networks) and the on line data interface for each generator/consumer in respect of the energy generation/consuming process in the local network so as to evaluate the electricity cost in a free market.

Taking into account the problematic in the field, in the next paragraph we will present the identified solutions suite of a scientific literature analysis.

Experimental study

In the following paragraphs will be presented the major steps made to design and realize a fuzzy logic controller for the low voltage electrical networks with distributed power generation from renewable energy resources, in order ensure the network stability and to support with an intelligence tool the process.

Experimental plant

There were several projects at national context in RES field. In 1998 in Valahia State University was implemented the first project (ICOP-DEMO 4080/98) [2] for photovoltaic power stations connected to low voltage networks that integrate photovoltaic panels from buildings (the concept BIPV), a project financed by the European Union. This project was followed by the project CEEX CoFoTerm [1] that implemented the first experimental electrical network model with distributed power generation from Romania. These two major project have furnished the experimental data and the know how of the experts involved for this work research.

Simulations tests conditions

The tests simulations have been made under some constraints:
The experts decide that a stable network must have an operating tolerance rage (± 0.3 from DPcg - the difference between generated and consumed energy power).

On the other hand, the monitoring data have been initially analyzed and processed in order to optimize the stability control based on the existed know how in the field, the identified disturbance sources and correlation statistical coefficients.

Finally, the management energy economic conditioning factors (like storage energy cost, national energy price, amortize prices) have been included in the loss function to be optimized [4], [5]. Experimental data and the know how of the experts involved for this work research.

Simulation models

The figure 2 represent the architecture proposed and is an alternative to classical control structures based on human experts experience usually implemented in low voltage electrical networks with distributed power generation. It is implemented using a simplified and users' friendly Computer Aided Design package Fuzzy Logic Control Toolbox [3], existing in MATLAB® 6.0 software from MathWorks.

We focus the following paragraphs over the fuzzy controller design.

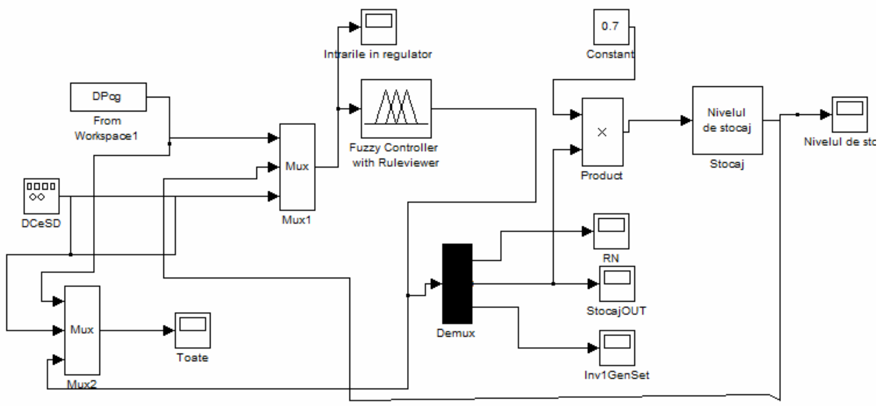


Fig. 2. The simulation block scheme.

Through the use of membership functions defined for each fuzzy set for each linguistic variable, the degree of membership of a crisp value in each fuzzy set is determined. The numerical variables units are:

"DPcg" (the difference between generation and consuming power) was fuzzified using 4 trapezoidal membership functions with these following significations: "BigNegative", "Negative", "Positive" and "BigPositive".

" DCeSD " (the difference between the storage energy costs and produced using controlled generators energy costs) was fuzzified using 2 triangular membership functions- "Negative" and "Positive".

"Storage" (the existing energy level in stocks or in the permanent generators) was fuzzified using 2 triangular membership functions: "Empty" and "Full"

The memberships assigned to the controller output are:

"RN" and is supposed to have trapezoidal shape with 2 fuzzy partitions. The linguistic term sets are labeled function of the assigned performed action: the production in national energy network

"DebRN" or the alimentation from national energy network "TakeRN".

"StorageLevelOUT" represent the fuzzy controller output who conditions the open or the close of the accumulators for energy storage. This one is represented with 2 triangular membership functions: "LoadStorage" and "TakeStorage".

The third output is "OffInv&GenSet" and influence the switch on of the networks invertors or of the controlled power generators (where "OffInv" and "GenSet" are the 2 triangular associated membership functions).

In the inference process, using IF THEN rules, the dynamic of the process are described. Using a min-max inference technique, for the 3 inputs 3 outputs fuzzy controller, 7 rules are built:

R1: IF (DPcg is BigNegative) AND (Storage is Full) THEN (StorageLevelOUT is LoadStorage) Or
R2: IF (DPcg is BigPositive) AND (Storage is Full) AND (DCeSD is Negative) THEN (StorageLevelOUT is TakeStorage) and so on…

The last phase in the modeling fuzzy expert system is the defuzzification of the linguistic values of the output linguistic variables into crisp values. The used technique for defuzzification is "som".

The results

The figure 3 represents the simulation results for the folowing scenario: the storage element is emty and the cost of the energy produced using controlable generators is smaler than the cost of the energy used from the acumulators.

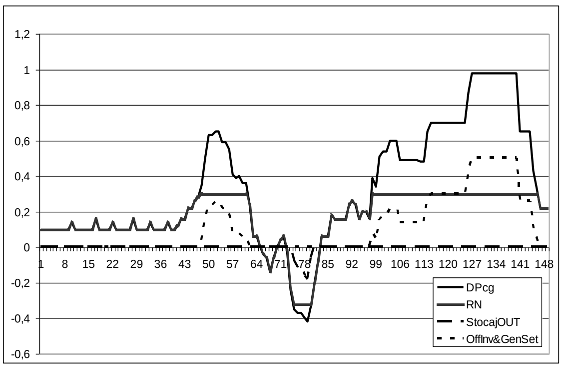


Fig 3. Scenario 1: storage empty and DceSD negative**.**

We can observe that during a regular day, in overgeneration moments due to the high level of solar radiation and other environmental factors, the storage elements will be swich on. When we have and undergeneration meening the consumers demands exeeding the production capabilities, the energy will be taken from the generators.

In the second scenario (figure 4) the storage element is emty and the cost of the energy produced using controlable generators is biger than the cost of the energy used from the acumulators. The decisions taken during a regular day will be this time complementary to those described for the first scenario.

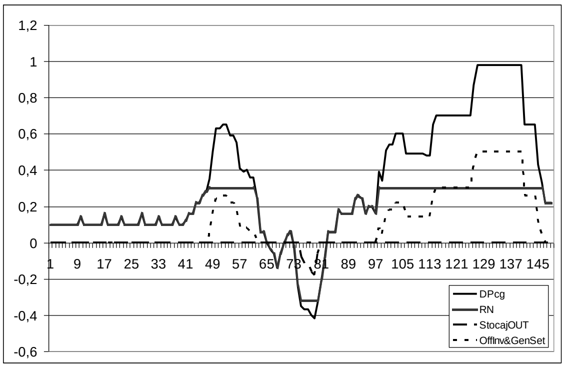
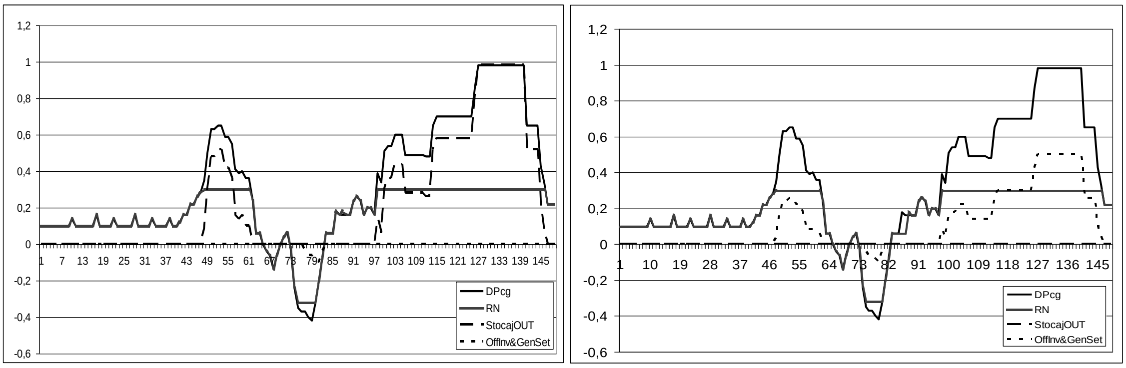


Fig 4. Scenario 2: storage empty and DceSD positive.

The third simulation situation has as hypotheses: the storage element is not empty and the costs of energy in national network exceed the cost of storage energy. Thus, the shape of DPcg, RN, StorageOUT (figure 5 a)) will help the deciders to take the optimum decision. The complementary situation is represented in figure 5 b).



a) **b)**

Fig 5. Storage full and DCeSD positive a) and Storage full and DCeSD negative b).

The logical scheme (figure 6, on the next page) points out the steps to be followed for ensuring network stability in all possible situations.

Conclusions

This paper proposes an engineering solution for the stability control of the low voltage electrical networks with distributed power generation from renewable energy resources.

The performances of this proposed software instrument can be improved with an optimal modelling of a rule base on an inference engine. We precise that out proposal is only the simply version of an intelligent management system that will be implemented on the experimental model of a low voltage electrical networks with distributed power generation from renewable energy resources, existing in DCEM- UVT research department.

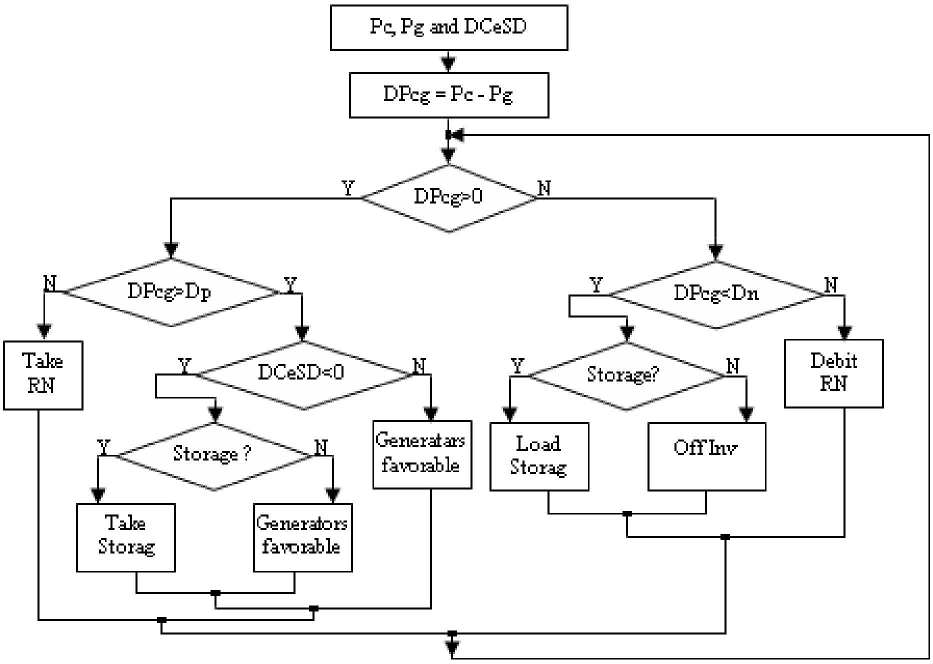


Fig 6. Logical scheme.

In order to test the conformity of the results with the energy quality standards, the simulations tests will be made with real monitoring data and the FLC architecture will be improved with new scenario in order to increase minimal intelligence level established in initial modelling phase.

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Studiu experimental de stabilitate pentru sisteme inteligente de control de rețele electrice de joasă tensiune cu PD-RES folosind controler fuzzy

Rezumat

Acest articol propune o soluţie inginerească pentru controlul stabilităţii reţelelor electrice de joasă tensiune cu distribuţie de energie din resurse regenerabile de energie. În primul rând sunt prezentate, în mod general, problemele existente în acest tip de sisteme, posibil a fi rezolvate cu ajutorul sistemelor de control automat inteligente. În a doua parte, propunem un instrument de control inteligent realizat cu în Matlab®. Mai precis lucrarea se va concentra asupra controler-ului fuzzy ce funcţionează pe baza datelor experimentale monitorizate de la o aplicaţie reală şi pe experienţa experţilor.

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