DEFINITION OF OPERATING SYSTEM OF DISTRIBUTED GENERATION SOURCES THROUGH THE APPLICATION OF MACBETH MULTICRITERIA METHOD FOR DECISION MAKING

Canha, L.N.; Barin, A.; Santos, A.C.F.R.
Center of Studies in Energy and Power System
Federal University of Santa Maria
Santa Maria, Brazil
lucianecanha@gmail.com, chbarin@gmail.com,
frs.anacarolina@gmail.com

Brignol, W.; Azevedo, R.
IFSUL/campus Pelotas
Pelotas, Brazil
wagner.brignol@gmail.com,
rodrigo_motta@pelotas.ifsul.edu.br

Abstract – **Considering that connections of distributed generation (DG) sources may cause positive and/or negative impacts in several technical aspects of a distribution network (DN), the definition of the moments in which the DG should dispatch energy is crucial for this connection occurs when it is really necessary for the distribution system.**

Therefore, this work presents the development of strategies for the definition of DG operating system through the application of multicriteria method MACBETH for decision support, so the DG can dispatch electricity in a DN reaching the levels of power quality.

To apply the methodology, a case study was performed in which was determined the operating procedure of the DG to be connected to a DN in the coalfield of Rio Grande do Sul, obtaining a rank of the hours that the energy generated by the DG is dispatched.

Keywords – **Decision-makers, Distributed Generation, Macbeth Method.**

I. INTRODUCTION

Usually, the best option to be made by an expert or decision agent (DA) should not be based on a single criterion. It is important that a set of alternatives for a given problem should be analyzed by more than one criterion, according to mutual agreement of interests and judgments between the DAs.

A multicriteria process of decision support aims to provide a higher degree of conformity and coherence between: the evolution of a decision-making process and systems of values and goals of those involved in this process. For this purpose, concepts, tools and procedures should be designed to make a choice in the presence of ambiguity and uncertainty. Multicriteria processes have shown far superior results than single criterion approaches, which base their logic on economic rationality, ignoring the private interests of those involved in the decision-making process [1].

Stipulate the procedure in which a DG connected to a DN should operate considering only one criterion can be foolhardy, since the dispatch of electricity by the DG at inappropriate moments may cause several negative impacts such as the increase of voltage levels in the network, of power losses, of the loading of conductors, among others. Therefore, to determine the operating regime of a DG by using multicriteria methodologies is the most prudent.

II. APPLICATION OF THE METHODOLOGY

The multicriteria method MACBETH for decision-making involves the structuring of multicriteria of choice in a hierarchy tree, enabling the evaluation of these criteria through DAs. In this work, the DAs are experts from the electricity distributor and from the DG.

The DAs together assign the value of each criterion in the decision-making process in order to obtain as result a ranking of the hours in which the energy generated by the DG should be injected in the distribution system.

To apply the methodology, a case study was performed in which a biogas DG with generation potential of 6 MW of electricity would be connected to a DN located in the coalfield of Rio Grande do Sul [2]-[8], as shown in Figure 1.

This DN operates with a working voltage of 23 kV and maintains a coal mine (higher load) and several commercial, industrial and residential (urban and rural) consumers.

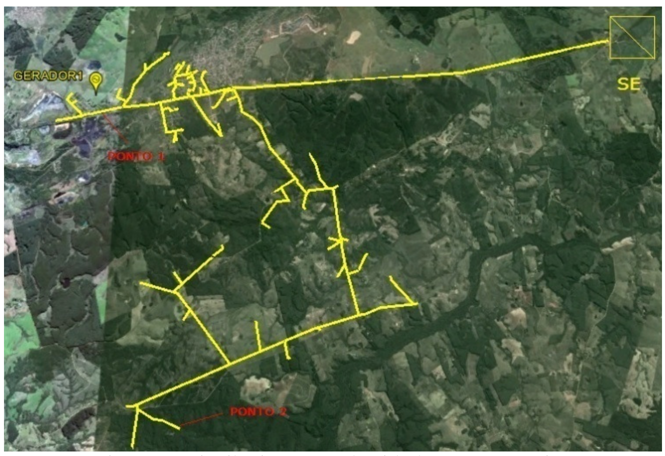

Figure 1. Distribution network with the DG connection.

ELETROSUL S.A, , R&D ANEEL, CAPES e Programa PNPD

A. Criteria for the definition of the DG operating system

Quantitative and qualitative criteria were considered in order to obtain more adequate results. Quantitative criteria are represented by real data that directly indicate the value of each technical characteristic in the process. The quantitative criteria used in this work are: voltage levels (VL) in a steady regime; DN power factor (PF); loading of the trunk conducting cables (LTCC); active power losses (P_kW).

Qualitative criteria are those that exhibit inaccurate values and difficulties in their quantification. The qualitative criteria used in this work are: Ancillary Services (AS), possible of being provided by DG: Active Power Reserve and Support of Reactives [3]-[4].

Each quantitative and qualitative criterion must have its limits and restrictions measured by DAs, in accordance to technical and operational aspects of the DN in which the DG will be connected.

B. Criteria modeling

Being the qualitative and quantitative criteria defined, the five modeling steps of the method have to be performed in the M-MACBETH software [5]:

- *Formulation of the hierarchical tree of evaluation, as illustrated in Figure 2.*

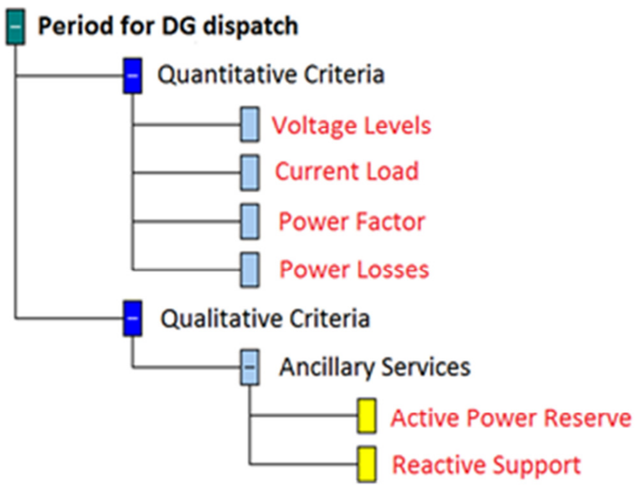

Figure 2. Hierarchical tree of evaluation.

- *Definition of the alternatives:*
  The alternatives are represented by the 24 hours of the day that is possible to connect the DG to the DN.

- *Definition of the classification of each criterion regarding to the basis of comparison:*
  For quantitative criteria, the comparison basis of the criterion is indirect, in other words, the evaluation of the importance of the alternative in the criterion is done indirectly through the use of a scoring function. This function converts the values of the alternatives performances in scores. Each scoring function has an upper and a lower limit. The upper limit represents the maximum importance and is equivalent to 100 (one hundred). The lower limit represents null importance and is equal to 0 (zero). For the qualitative criteria, the basis for comparison is also indirect and using limits (upper and lower) but without using a scoring function to ponder the criterion.

- *Definition of the scoring function, upper and lower limits of each criterion:*
  The scoring function of each criterion converts the values of the criteria performances in scores as follow: in each time of the day in which the value of the criterion performance is equal to the value established as lower limit of the function, the score established by the method will be zero, meaning that the dispatch of electricity by the DG in the DN is not necessary. When the value of the criterion performance is between the established values for the upper and lower limits, the score established by the method is higher than zero and lower than a hundred. This value (importance for the dispatch) is defined according to the linear function elaborated by the DA and so, the dispatch of electricity by the DG to the DN is needed.
  When the value of the criterion performance is equal to the upper limit established, the score set by the software is maximum and equal to a hundred. So, a maximum dispatch by the DG in the DN is needed. For the definition of the functions and limits of each criterion, the DA used the following parameters:

  - VL and **PF:** both the function and the values of the upper and lower limits of the criteria function were defined according to the values presented at Module 8 – PRODIST 2010 [6];

  - LTCC: the lower limit equals to 50% of LTCC and the upper limit of the function is when the LTCC is 100%;

  - P_kW: For the DA determine the scoring function with upper and lower limits they used as a basis for their judgments the levels of active power losses obtained through the experimental calculations performed in some distributors. These calculations showed that even small DG sources installed in optimal points can reduce energy losses by more than 25% [7]. For this, the values for levels of losses presented in Table I were used [8].

  - Active Power Reserve and Reactive Provision: DAs have defined as upper and lower reference the need or not of the AS supply by the DG.

TABLE I.

Classification of Losses Levels in DN	
Low losses	Less than 2%
Acceptable losses	From 6 to 10%
High losses	From 10 to 14%
Excessive losses	Higher than 14%

- *Quantification of the value of each criterion and weighting pair by pair among the criteria*
  In this phase it is necessary that the DAs define the values of each criterion to obtain the final result. The amount of the values of each criterion must result in 100 points. Considering that the quantitative criteria are those that are currently regulated by the regulator agent or by the energy distributors, the DAs determined that the values of these criteria should have a predominant role in the definition of the DG operating regime/system, representing then 90% of the points divided as follow: VL = 45 points; LTCC = 22,5 points; PF = 15 points and P_kW = 7,5 points, being the sum equal to 90 points.
  Qualitative criteria represented by AS - "active power reserve" and "reactive provision" – are still not regulated by the regulator agent [9]. So, the DAs determined that these criteria should represent only 10% of the points. The DAs have defined also that the values of the two qualitative criteria are the same, being each equal to 5 points. With this step performed, the M-MACBETH software presents graphically the prioritization of the criteria according to the stipulated judgments by the decision agents, as shown in Figure 3.

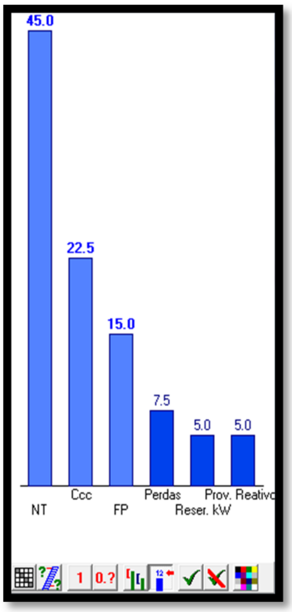

Figure 3. The value of the criteria according to stipulated judgments by DAs.

C. Conversion of the criteria functions to scoring

To do the conversion of the criteria functions to scoring is necessary the introduction of the performance values of each criterion – Figure 4. The values of the criteria performances were obtained through measurements of the electrical quantities of the AL occurred on January 11, 2012, when the largest loading of this distribution network happened in the past 24 months.

For the VL criterion, it was used the values of "point 2", because this point of the DN represents the lower voltage profile.

For the LTCC criterion, the percentage values of the loading of trunk conducting cables were used. The conducting trunks in the DN are 4/0 AWG CAA, and have a current carrying capacity of 282A.

For the AS criterion, "Active Power Reserve" is needed to the DG use in the moments when the DN loading reaches 5MW or more. In the other times the use of the DG is not necessary. And for the "Reactive Provision" criterion, the DAs defined that when the reactive loading of the DN exceeds 2MVAr it is necessary the DG use to perform the reactive support to the DN. In other moments, the DG use is not needed.

Opções	NT	Ccc	FP	Perdas kW	Reser. kW	Prov. Reativos
01:00	0.92	48	0.93	0.4	Não	Não
02:00	0.93	45	0.92	0.38	Não	Não
03:00	0.93	43	0.92	0.36	Não	Não
04:00	0.93	42	0.92	0.35	Não	Não
05:00	0.93	42	0.92	0.36	Não	Não
06:00	0.94	39	0.93	0.34	Não	Não
07:00	0.94	36	0.94	0.31	Não	Não
08:00	0.93	44	0.91	0.4	Não	Não
09:00	0.92	48	0.91	0.45	Não	Sim
10:00	0.92	50	0.91	0.47	Sim	Sim
11:00	0.91	52	0.91	0.48	Sim	Sim
12:00	0.92	48	0.93	0.44	Não	Não
13:00	0.92	50	0.92	0.47	Sim	Sim
14:00	0.91	55	0.92	0.52	Sim	Sim
15:00	0.91	57	0.91	0.55	Sim	Sim
16:00	0.91	56	0.91	0.54	Sim	Sim
17:00	0.91	54	0.91	0.52	Sim	Sim
18:00	0.92	47	0.93	0.43	Não	Sim
19:00	0.93	44	0.92	0.4	Não	Não
20:00	0.93	44	0.93	0.38	Não	Não
21:00	0.91	57	0.95	0.5	Sim	Não
22:00	0.92	54	0.96	0.47	Sim	Não
23:00	0.91	59	0.95	0.51	Sim	Sim
24:00	0.92	53	0.94	0.45	Sim	Sim

Figure 4. Performances table of the alternative for each criterion.

D. Results

Completed the implementation of all the steps, the final ranking of alternatives evaluated is obtained. In Figure 5, the final result can be seen with the ranking of the hours when the DC must dispatch electricity to the DN.

Opções	Global	NT	Ccc	FP	Perdas kW	Reser. kW	Prov. Reativos
[tudo sup.]	100.00	100.00	100.00	100.00	100.00	100.00	100.00
15:00	44.40	66.67	14.00	8.33	0.00	100.00	100.00
23:00	44.05	66.67	18.00	0.00	0.00	100.00	100.00
16:00	43.95	66.67	12.00	8.33	0.00	100.00	100.00
17:00	43.05	66.67	8.00	8.33	0.00	100.00	100.00
14:00	42.25	66.67	10.00	0.00	0.00	100.00	100.00
11:00	42.15	66.67	4.00	8.33	0.00	100.00	100.00
24:00	26.35	33.33	6.00	0.00	0.00	100.00	100.00
10:00	26.25	33.33	0.00	8.33	0.00	100.00	100.00
13:00	25.00	33.33	0.00	0.00	0.00	100.00	100.00
21:00	23.15	33.33	14.00	0.00	0.00	100.00	0.00
22:00	21.80	33.33	8.00	0.00	0.00	100.00	0.00
09:00	20.35	33.33	-4.00	8.33	0.00	0.00	100.00
12:00	14.10	33.33	-4.00	0.00	0.00	0.00	0.00
18:00	3.65	0.00	-6.00	0.00	0.00	0.00	100.00
[tudo inf.]	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01:00	-0.90	0.00	-4.00	0.00	0.00	0.00	0.00
08:00	-1.45	0.00	-12.00	8.33	0.00	0.00	0.00
02:00	-2.25	0.00	-10.00	0.00	0.00	0.00	0.00
19:00	-2.70	0.00	-12.00	0.00	0.00	0.00	0.00
20:00	-2.70	0.00	-12.00	0.00	0.00	0.00	0.00
03:00	-3.15	0.00	-14.00	0.00	0.00	0.00	0.00
05:00	-3.60	0.00	-16.00	0.00	0.00	0.00	0.00
04:00	-3.60	0.00	-16.00	0.00	0.00	0.00	0.00
06:00	-4.95	0.00	-22.00	0.00	0.00	0.00	0.00
07:00	-6.30	0.00	-28.00	0.00	0.00	0.00	0.00
Pesos :		0.4500	0.2250	0.1500	0.0750	0.0500	0.0500

Figure 5. Final ranking with the dispatch hours by the DG to the DN.

With the results presented in Figure 5, it is noticed that the most appropriate period for the connection of the DG source in the DN is 14 hours/day, in the intervals between 9:00A.M. and 06:00P.M., and from 09:00P.M to 12:00. The second column shows the scoring ranking of the ideal hours for the dispatch, being the best hour at 03:00P.M.. The hours in which the score resulted in negative numbers mean that in these hours the DG should not dispatch electricity to the DN, and at 07:00A.M. is the less suitable moment for power generation.

The application of MACBETH method, using four quantitative criteria and two qualitative criteria, resulted in an operating regime of the DG in which it should be connected to the DN for 58,33% of the day.

III. CONCLUSIONS

As many aspects of distribution networks are influenced by the connection of DG sources, it is important not to have just one criterion to define the operating regimes of these sources, but several. In this way, the application of multicriteria methodologies is more adequate. These methodologies use concepts, tools and procedures to help make the better choice in the presence of uncertainty, resulting in more efficient operating systems. It is important to notice that when more criteria are considered, or when the values assigned by the DAs are changed, the final results may change significantly.

The application of MACBETH multicriteria methodology allows to define an operating regime for the DG and to obtain a ranking of the best hours to connect the DG to the distribution network. This ranking is important for the distributor and the energy producer to evaluate and decide in which moment of the day is less harmful for the system the disconnection of the DG, when the generator needs to be turned off for maintainance, for example.

Finally, the importance of studies and researches that seek to demonstrate the impacts of the DG in distribution systems must be emphasized. They will serve as subsidies for electricity distributors see the possibility of the DG use as a way to help them achieve the quality indicators of energy and increase the reliability of their distribution systems.

IV. ACKNOWLEDGEMENT

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