DETERMINATION OF A MINIMUM PROTECTIVE SYSTEM FOR DISTRIBUTION SYSTEMS EMBEDDED WITH SMALL SOURCES OF DISTRIBUTED GENERATION

Luis POZZATTI
UFSM – Brazil
fila.rs@gmail.com

Alexandre BARIN
UFSM – Brazil
chbarin@gmail.com

Cássio CARVALHO
UFSM – Brazil
cassio_giuliani@hotmail.com

Luciane CANHA
UFSM – Brazil
lncanha@ufsm.ct.br

Ricardo MACHADO
UFSM – Brazil
ricardombr2002@yahoo.it

Alzenira ABAIDE
UFSM – Brazil
alzenira@ct.ufsm.br

Felix FARRET
UFSM – Brazil
faf@ct.ufsm.br

Carlos FERNADES
CEEE-D - Brazil
CarlosMF@ceee.com.br

ABSTRACT

In last years, the Brazilian electric sector is watching an increased growing in the participation of distributed generation (DG) sources. Mainly, at voltage levels of 23 kV and 13.8 kV, typical for grid medium voltage, the impacts caused by low power generators may lead to several technical and economical problems. Fault levels alteration, distribution system instability, islanding in parts of the system and increased interruption duration are some of these problems. Hence, this paper treats about the effects produced by the insertion of low power DG sources in the distribution system, particularly of synchronous machines. In the future, the results obtained here could be used to help determining a standard protective system and to decide about the decisions to be taken over DG installation to prevent them to represent any harm to the distribution system. The considerations and results presented in this paper are part of a Research & Development Program of the State Company of Electric Energy (CEEE-D) and executed by the Federal University of Santa Maria (UFSM).

INTRODUCTION

Utilization of DG sources to minimize the increased demand problems has been a solution every more and more wanted nowadays. Not to mention its reduced size and modularity, many DG sources are environmental friendly, taking advantage of the renewable resources and decreasing the impact over the nature. Technically, they bring a lot of benefits such as improving the voltage levels, reducing power losses, allowing the use of cogeneration systems, among others [1].

On the other hand, it is necessary a detailed evaluation of the main grid reaction to where the DG is going to be installed, what load type will be supplied, and working regimes, otherwise, the impacts caused by DG could be more harmful than beneficial. New generation sources coupled to the distribution system cause transient disturbs due to the parallelism maneuvers, change the fault and stability levels, leading to misoperation of protection devices [2] and islanding of system parts.

The Brazilian legislation has stimulated the development and implementation of alternative energy sources by self-producers and independent producers. Moreover, no specific regulation about protection devices has been used up to now, and each electric energy company decides which one is their more adequate protection system. This legal gap brings some confusion to someone who wants to install DG in grids administrated by different companies, because the requirements can change significantly from one to another. The goal of this paper is to show a dynamic analysis of when low power sources, ranged between 50 and 1000 kVA, are inserted into the grid. In the future, these data could be used to enroll a standard protection system to take care of legal requirements for the electric energy company and self-producers or independent producers.

What follows, is a discussion about the main problems caused by coupling new generation sources to distribution systems.

Fault level modification

Depending on the position the DG source is installed, respective to main source and overcurrent relaying positions, different alterations of fault levels may happen [3].

When DG is connected as indicated in Fig. 1, the DG contributes for an increased fault current that will be seen by the relay. This condition makes the protection device operates faster, demanding an adjustment on the relay curve, so that operative coordination will not be lost.

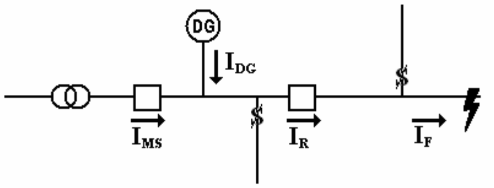


Fig. 1. DG installed before the relay and the fault point

Where:

I_{MS}: fault current parcel provided by the main grid
I_{DG}: fault current parcel provided by the DG source
I_R: fault current parcel seen by the relay
I_F: overall fault current

The situation illustrated in Fig. 2 indicates a decreased fault current as seen by the relay. In this case, it is necessary an increased relay sensibility, so that it can operate when any faults occur.

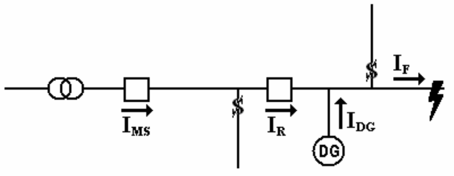


Fig. 2. DG installed between the relay and fault point

A third case arises when the DG installation reverses the current flow seen by the relay (Fig. 3). Here, two solutions are possible: relocation of the relay or its replacement by a directional type relay.

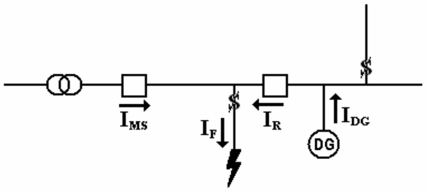


Fig. 3. DG installed after the fault point and the relay

Islanding

Faulted parts of the distribution system are disconnected by operation of protection devices. When there is a DG source connected to the main grid, the islanded part may remain operative. In most cases, islanding is not desirable for the following reasons [4]:

- Reconnection of the islanding part becomes complicated, especially when automatic re-closure is used. Besides, this it can cause damages to the equipment and a decreased system reliability;
- Network operator is unable to guarantee the energy quality in the island. Could appear abnormal voltage and frequency, and the protection system could not operate satisfactorily;
- Safety problems to maintenance personnel arise when de-energized circuits are back-fed.

Anti-islanding specifications that guarantee the quality and reliability of the distribution system vary from country to country. But the requirements are similar in the following points:

- In the case of voltage or frequency abnormalities, the DG source must be disconnected from the main grid;
- If one or more phases are disconnected from the main grid, the DG sources must be disconnected as fast as possible;
- If automatic re-closure is used, the DG must be disconnected before the re-closure process.

Today, there are great problems for detecting islanding systems by the conventional methods.

Stability

As IEEE defines, a power system is stable under the transient stability point of view for a particular operating condition if, after a disturbance occurs, the system is able to achieve an acceptable operational condition.

In distribution systems the actuation times of the protection devices are relatively high and, additionally, the inertial constant of synchronous generators is low, usually less than 2 seconds. Therefore, the transient stability can considerably limit the quantity of active power supplied by distributed generators [5]. Furthermore, this paper deals with low power generators, since when the number of machines coupled to the distribution system increases, it may achieve this power limit, causing instability in the system.

The purpose of following simulations is to identify the effects produced by installation of DG sources along the distribution system. Based on these results, future decisions will be taken and adequate protection devices will be suggested to minimize the previously mentioned problems, or even eradicate them altogether.

SIMULATIONS

The set of simulations were realized in two stages. The first, in the software ATP, with which could be simulated a complete distribution system and the DG source coupling, represented by a synchronous machine of low power (100 kVA). As a control system for the machine was not implemented until that moment, only the effects caused by coupling the DG to the main grid, without power transfer, were evaluated.

Fig. 4 shows the distribution system to be analyzed in the simulation. All loads are of the RL type with random power factors between 0.89 and 0.98. There is not any kind of tap adjustment in the distribution transformers, being acceptable the terminal voltages go sometimes under the allowed level.

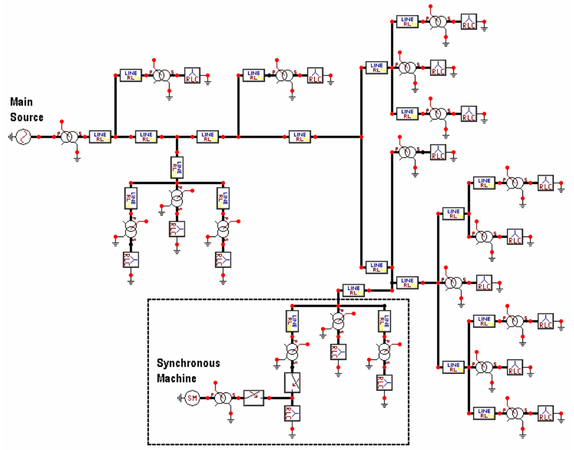
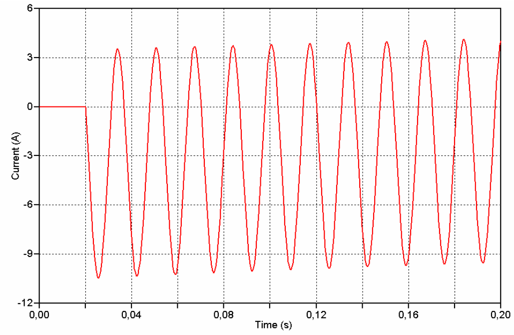


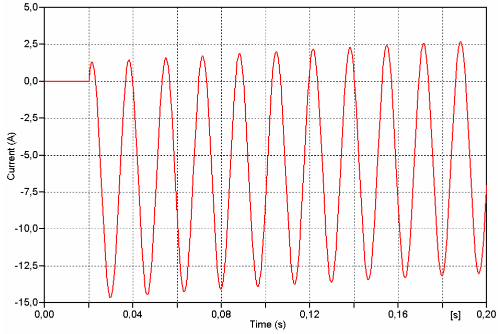
Fig. 4. ATP simulated circuit

As of a good practice, to couple the DG source to the main grid, it is important to verify at the instant of parallelism closure, whether the machine voltages have the same amplitude, frequency and phase angle that the correspondent main grid voltages. Thus, it is safer if the machine enter in a floating state, without any power transfer. Otherwise, the bigger the difference between the voltage amplitudes or the voltage phase angles, the bigger will be the current supplied by the machine to compensate such differences.

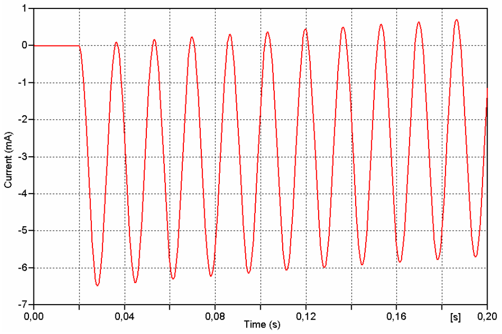
Fig. 5 shows the current behavior as supplied by the synchronous machine when the parallelism is made under different situations: a) when DG voltage leads the main grid voltage by 5°; b) when there is a difference of 10% between DG and the main grid voltage amplitudes; c) when the amplitude and phase angle differences between DG and the main grid are under 0.1% and 0.05°, respectively.



(a) DG voltage leading the main grid voltage by 5°



(b) DG voltage is 10% above the main grid voltage



(c) when DG and main grid voltages are practically equal

Fig. 5. Synchronous machine currents

As can be seen through the results, the current supplied by the machine is closer to zero as the ideal situation is achieved (Fig. 5c). All graphics in Fig. 5 have an average component, displacement of the average value, which is eliminated as the time goes ahead.

The second stage of simulations was realized in the software MatLab®, with the equivalent circuit seen in Fig. 6 for the detached part in Fig. 4. In this stage, the effects caused by coupling the DG to the distribution system were analyzed including load transfer.

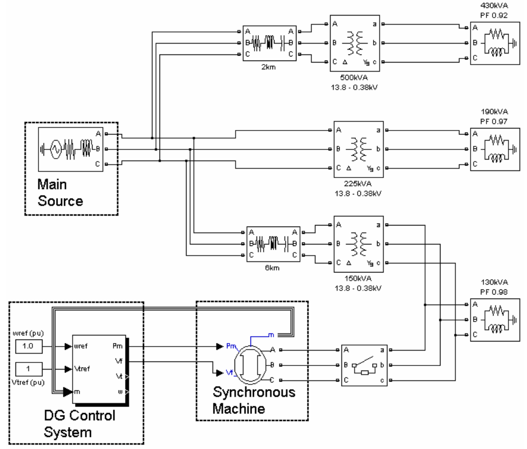
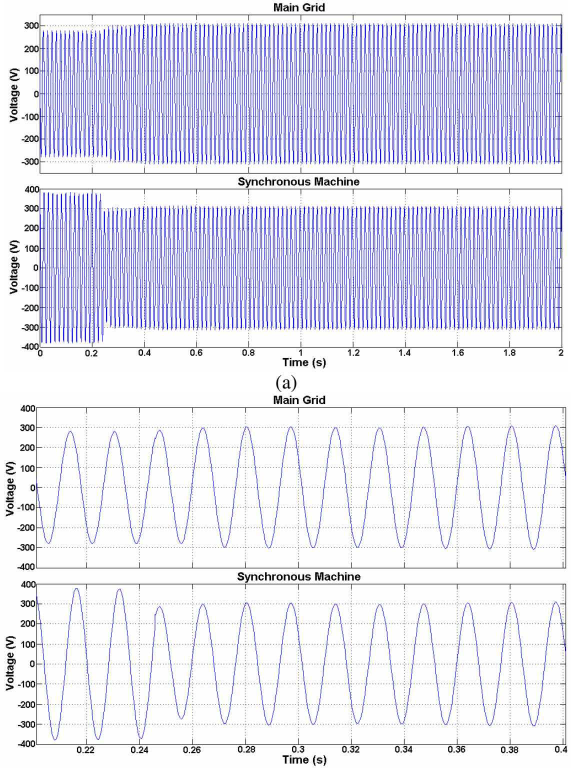


Fig. 6. MatLab simulated circuit

In Fig. 7a can be noticed that, from the moment DG is coupled to the main grid, there is an improvement of voltage levels being supplied to the load. And, at the same time, there is a reduction in voltage levels at the synchronous machine terminals. In Fig 7b, can be better observed the effects originated at the moment the parallelism was closed.

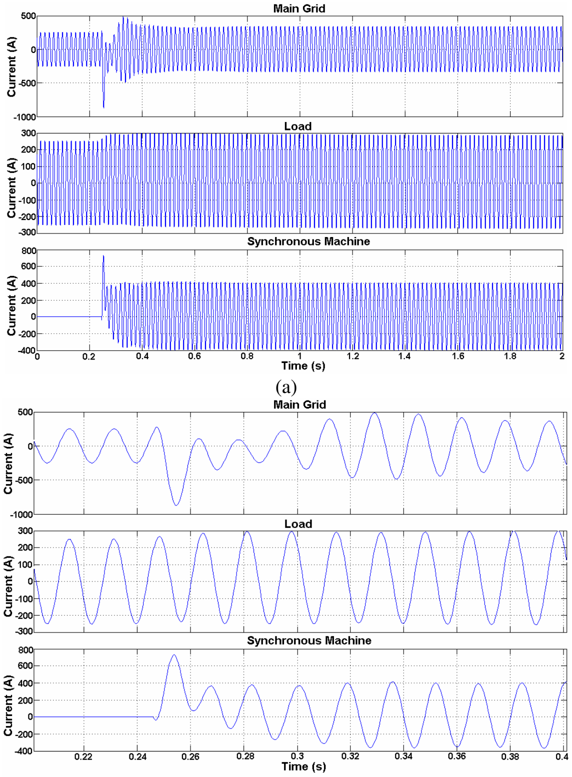


(a)

(b)

Fig. 7 Voltage behaviors in the moment the parallelism is closed

Relating to the currents, at the moment the parallelism was closed, there are oscillations in the contributions to the load supplied by the main grid and the DG (Fig. 8a). However, the total current demanded by the load remains practically unchanged. The most significant alteration in the load current is the increased amplitude, stimulated by the improvement of the voltage levels. In Fig 8b, it is better seen the effects originated at the instant the parallelism was closed on the currents.



(a)

(b)

Fig. 8. Current behaviors in the moment the parallelism is closed

CONCLUSIONS

As it could be seen through simulation, installation of DG sources in parallel with the distribution system may cause undesirable effects. It is important to establish ideal conditions for the synchronism between the DG and the main grid, so as to minimize the interferences caused by the coupling procedures.

In this project, the software ATP was preferred with respect to others because it is more usual for the energy companies and they are already acquainted to it. As soon as the control system of the synchronous machine is implemented in ATP, all simulations will be made in this software, rather than MatLab.

Results from the transient state analysis also contribute to decide about selection of the criterion to be used to obtain the best place where to install the DG source in a multicriterial basis study. The presented results extend the vision about the impacts caused by DG sources of low power installed along distribution systems at voltages of 13.8 kV and 23 kV. Moreover, they could support planning studies to determine the best installation place of a DG system.

Next steps in this research are the implementation of system control for low power synchronous machines in the software ATP and, after that, how to obtain a minimum set of requirements for the DG protection system.

Acknowledgement

The authors would like to thank CEEE for their financial support given to this project.

REFERENCES

[1] W. El-Khattam and M. M. A. Salama, 2004, “Distributed generation technologies, definitions and benefits”, *Electric Power Systems Research,* Vol. 71, Issue 2, 119-128.

[2] S. Chaitusaney and A. Yokoyama, 2005, “Impact of Protection Coordination on Sizes of Several Distributed Generation Sources”, *The 7th International Power Engineering Conference*, 1-6.

[3] M.T. Doyle, 2002, “Reviewing the impacts of distributed generation on distribution system protection”, *Power Engineering Society Summer Metting 2002*, IEEE, Vol. 1, 103-105.

[4] L.K. Kumpulainen and K.T. Kauganiemi, 2004, “Analysis of the impact of distributed generation on automatic reclosing”, *Power Systems Conference and Exposition 2004*, IEEE, Vol. 1, 603-608.

[5] W. Freitas et al, 2005, “Revista Controle & Automação”, Vol. 16, Issue 3, 332-344.