Analysis of Micro Generation Impacts in Distribution Networks

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Abstract

The actual re-regulation phenomenon has been changing the exploitation, management and control power systems paradigms Next years will testify new changes because the advent of large scale micro generation integration in Low Voltage grids. In this sense, the present work analyzes the impact micro-generation on Medium Voltage (MV) and High Voltage (HV) electricity distribution networks.

Different networks types (HV, Rural MV, Semi-Urban MV and Urban MV) were simulated in different exploitation scenarios (Summer, Winter, Valley, Peak and In Between Hours) with different levels of micro generation penetration. The micro generation impact is evaluated through the alterations provoked in voltage profiles, power losses and branches congestion. The results show that a micro generation penetration increase favours networks operating conditions.

Keywords: Distribution systems, dispersed production, renewable energy

1. Introduction

Biosphere importance is sometimes forgotten with the industrialization and market competitiveness increase. In name of the progress, the environment is being exploited more and more and natural resources are becoming exhausted. Then, urgent measures must be taken to allow the reduction of the greenhouse effect gases emissions by increasing the use of renewable resources.

An important contribution can be provided by the micro dispersed generation (MG), through the investment in micro wind turbines, photovoltaic panels, micro hydro units, micro turbines powered by biodiesel or natural gas and fuel cells, both intended for Combined Heat and Power (CHP). These technologies allow local renewable resources to be exploited and/or increase the global efficiency when using fossil fuels. Moreover, as shown later in this paper, MG contributes also to power losses decrease.

In this sense, the present work analyzes the micro generation influence in electricity distribution networks.

Different networks types (High Voltage, Rural Medium Voltage, Semi-Urban Medium Voltage and Urban Medium Voltage) were simulated in different operation scenarios (Summer, Winter, Valley Hours) with different levels of micro generation penetration.

The analysis of the micro generation impact was performed using the following approach:

1. The integration of MG integration was performed by reducing the active power values in load buses.
2. Load flows were performed to obtain the new voltage profiles, level of losses and network branch congestion.

Results show that an increase in the micro generation penetration level largely favours network operating conditions.

2. Networks General Characterization

The data used for this study represents typical distribution grids from Portugal and it is fully described in [1].

A general characterization of each network under analysis is given next :

1. *High Voltage (HV) network*, having as injector node 1, is an aerial network of 63 kV with 5 buses and operated in an open loop way. The loop is opened between nodes 5 and 7 (Fig. 1).
2. *Rural MV network* (RMV), having as injector node 119), is a network of 30 kV (Output 1) that feeds 34 load nodes, being one of them a 30 / 15 kV substation. This substation has 3 outputs at 15 kV (outputs 2, 3, and 4) feeding 175 load nodes. These networks have both overhead lines and underground cables.
3. Semi-Urban MV network (SUMV) has 372 load nodes and three injectors of 15 kV that feed three different networks. The network possesses both overhead lines and underground cables; Areas fed by the different injectors were denominated as Area 1 (fed by the node 332), Area 2 (fed by the node 158) and Area 3 (fed by the node 267).
4. *Urban MV network* (UMV) has a single injector at 15 kV (node 095), feeding 7 outputs through cables (denominated as output A to output G). The network possesses a large reconfiguration capacity and has a total of 153 load nodes.

The corresponding network topologies are presented in the following Fig.s:

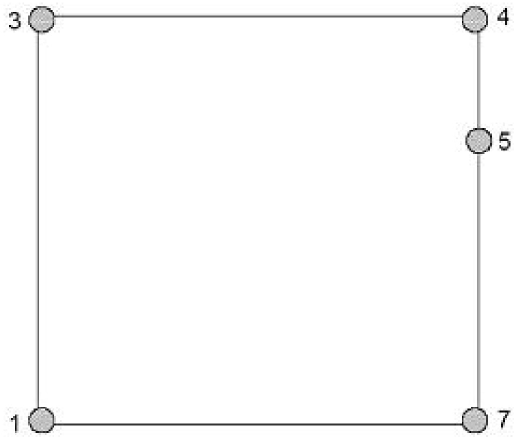

Fig. 1. High Voltage Network

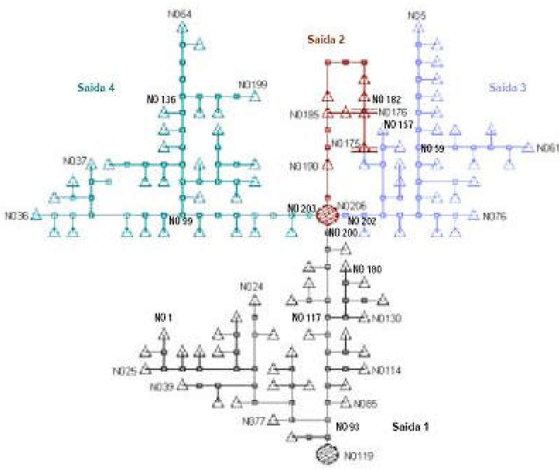

Fig. 2. Rural Medium Voltage Network

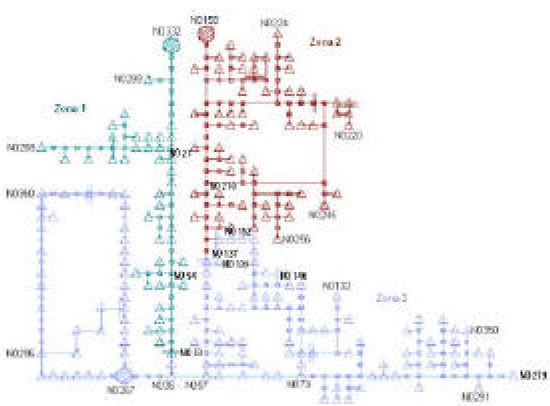

Fig. 3. Semi-Urban Medium Voltage Network

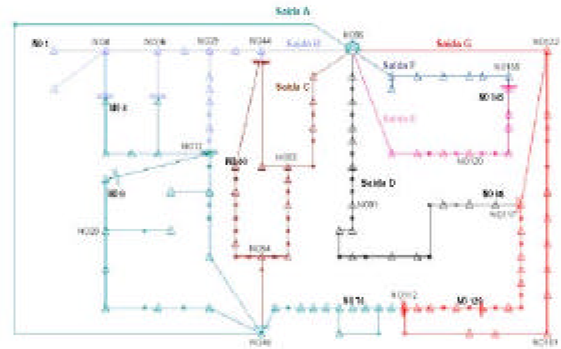

Fig. 4. Urban Medium Voltage Network

3. Studies

A. Data

For the HV, RMV and SUMV networks the following operation scenarios were considered: Peak Hours of Winter (PHW), Peak Hours of Summer (PHS), In Between Values of Summer (BVS), In Between Values of Winter (BVW) and Valley Hours of Summer (VHS). For the Urban Medium Voltage network case the following operation scenarios were considered: In Between Values (BV), Peak Hours (PH) and Valley Hours (VH).

For each load scenario, several other scenarios have been considered regarding power factors in the loads: from 0.0 to 0.6 in steps of 0.1.

B. Algorithm

For each situation described above:

- The impact of micro generation is treated by performing a percentage reduction in the amount of Active Power consumption in several load nodes.

- Network simulation and analysis is then performed through the following steps:
  1. Run load flow (a Newton – Raphson algorithm was used);
  2. Evaluation of total losses and branch loads;
  3. Quantification of the total load of the network.
  4. The network micro generation percentage (penetration), which results of active power consumption reduction in the referred nodes, is given by the ratio between the network total load variation before and after the active power decrease and the initial network total load.

4. Results

Next Fig.s illustrate the results obtained regarding voltage profiles variations, active and reactive power losses and branch load with different levels of integration of micro generation (given in percentage) for the four considered networks.

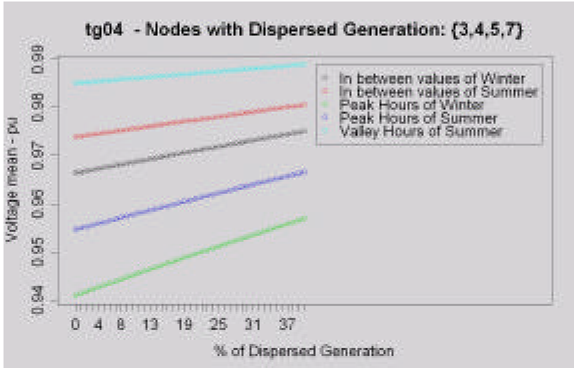

Fig. 5. HV Network – Voltage mean

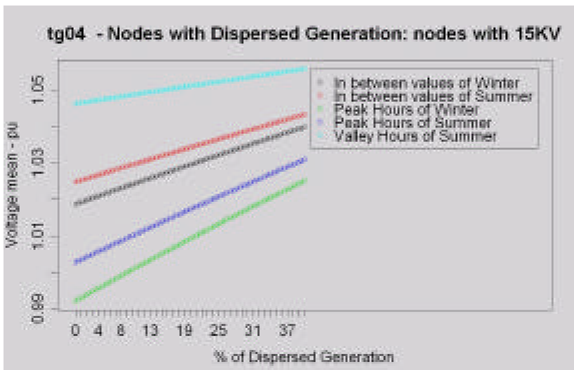

Fig. 6. RMV Network – Voltage mean

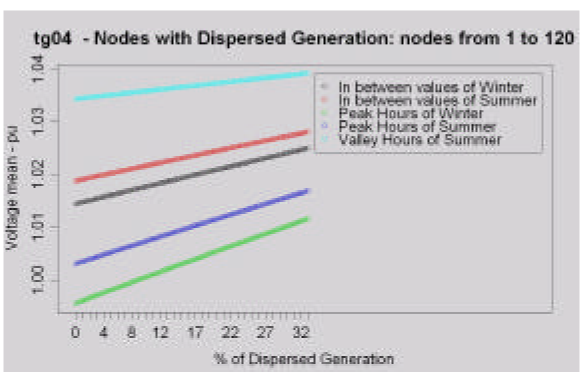

Fig. 7. SUMV Network – Voltage mean

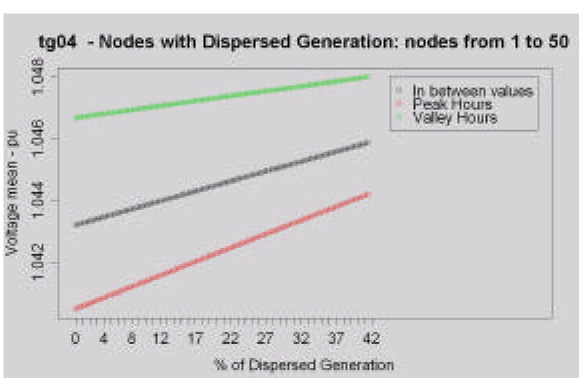

Fig. 8. UMV Network – Voltage mean

For a matter of simplicity, only the graph corresponding to tg ϕ = 0.4 in the loads is shown. The other studied scenarios (tg ϕ = 0, tg ϕ = 0.1, tg ϕ = 0.2, tg ϕ = 0.3, tg ϕ = 0.5 and tg ϕ = 0.6) are omitted because they present a similar behaviour.

A. Voltage Profiles Impact

For each one of the situations referred before the voltage value in each network node is calculated from the load flow solution for each considered tg ϕ. A graph with the average nodes voltages values of the network, as a function of the micro generation penetration level, is presented. The goal is to become aware of the voltage behaviour dependence on the level penetration of micro generation.

The graphics reveal that voltage profiles do improve with the increase in micro generation, since it corresponds to a decrease in load values. Furthermore, in the HV, RMV, SUMV networks, it is verified that the curves corresponding to the VHS, BVS, BVW, PWS and PHW situations appear in the presented order, from the highest to the lowest ???. In the UMV network, the VH, BV and PH curves occur in decreasing order of magnitude. This fact, is verified because as smaller is the energy consumption the larger is the voltage in each one of the nodes.

B. Active Losses Impact

The following graphs show the active power losses variation in the four networks for the considered operating scenarios, and for load tg ϕ = 0.4 case, as a function of the dispersed generation.

In these networks one can observe that active loss values decrease with the increasing of the micro generation level. It is also shown that in the HV, RMV, SUMV networks, the active losses curves appear in the following order (from lower to higher): VHS, BVS, BVW, PHS and PHW.

Loss reduction results obviously from the equivalent load consumption reduction (as seen from these network buses) that provokes a reduction in network branch currents and consequently reduces actives losses in each grid.

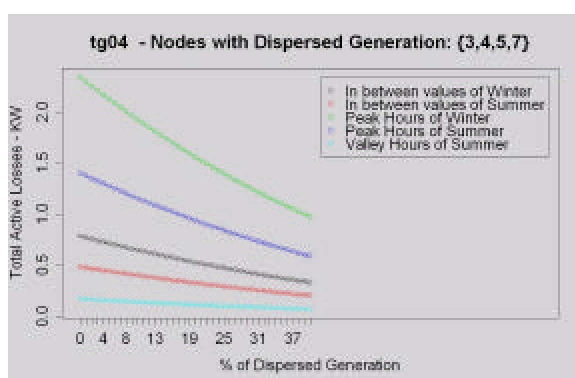

Fig. 9. HV Network – Active Losses

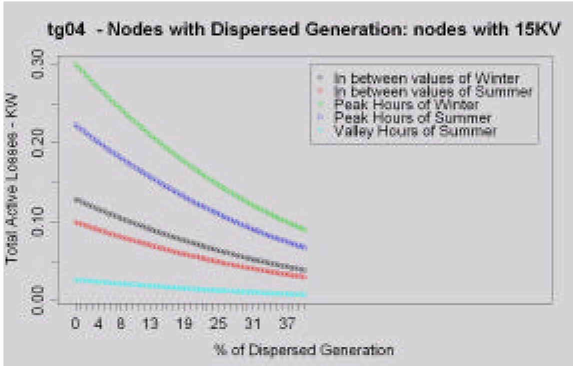

Fig. 10. RMV Network – Active Losses

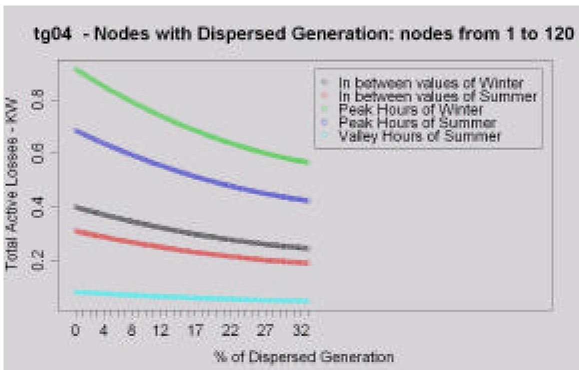

Fig. 11. SUMV Network – Active Losses

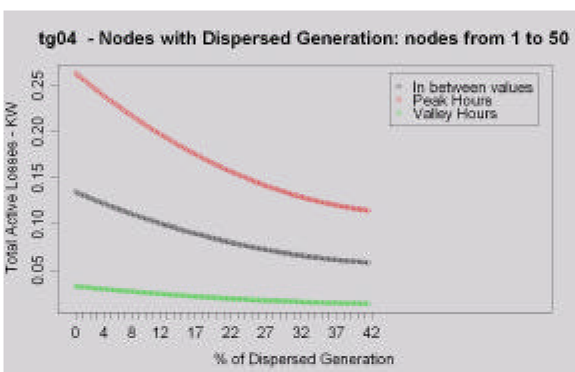

Fig. 12. UMV Network – Active Losses

C. Reactive Losses Impact

The following graphs show the reactive losses variation in the four networks for the considered operating scenarios, and for load tg $\phi = 0.4$ case, as a function of the dispersed generation.

In the four networks one can observe that reactive losses decrease with the increase of the micro generation level. It is clear that, in the HV, RMV, SUMV networks, reactive losses increase in the following order: VHS, BVS, BVW, PHS and PHW. In the UMV network the lowest Reactive Losses occur for the VH case and the highest for PH.

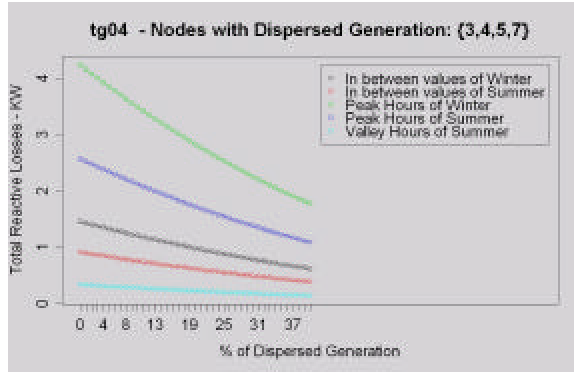

Fig. 13. HV Network – Reactive Losses

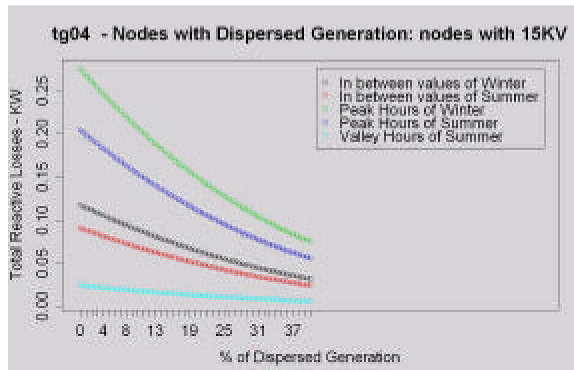

Fig. 14. RMV Network – Reactive Losses

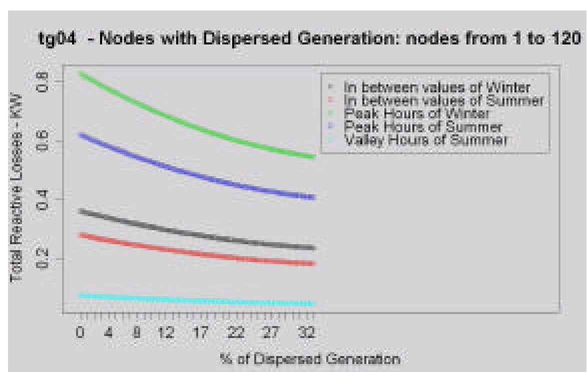

Fig. 15. SUMV Network – Reactive Losses

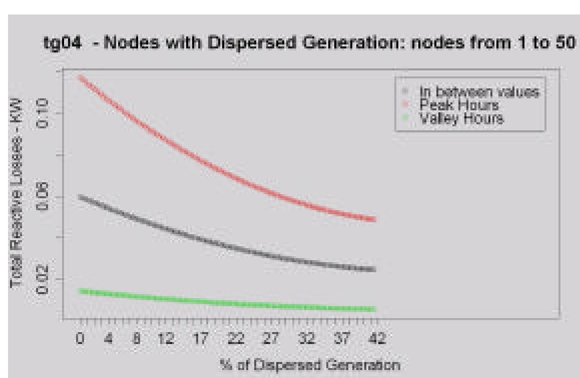

Fig. 16. UMV Network – Reactive Losses

This reactive loss reduction results from two reasons: a) the equivalent load consumption reduction (as seen from the network buses) that provokes a reduction in network branch currents and consequently reduces reactive inductive losses in each grid; b) the increase in the voltage network profile levels provokes capacitive reactive generation in lines and cables to increase, compensating partially, in this way, the local inductive reactive losses.

D. Active Energy Losses Impact

The computation of active energy losses was achieved by multiplying the active losses value by the number of hours considered for each load scenario.

For the HV, RMV and SUMV networks, one has considered 4 hours for the PHW and PHS load conditions and 10 hours for the other operating conditions. In UMV network one has considered 10 hours for BV and VH load conditions and 4 hours for the PH load scenarios.

Results show that as larger is the level of micro generation penetration the smaller is the amount of active energy losses value (as expected from the results obtained in section 4.B).

As expected, it was verified that for all the networks loss values are smaller in “Valley Hours” scenarios and larger in “In between values” (except in the HV network that the values are bigger in PHW situation).

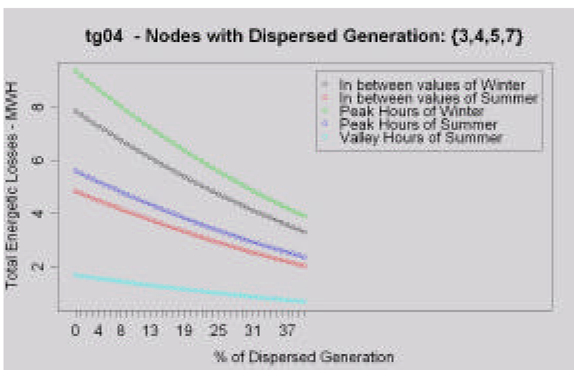

Fig. 17. HV Network – Energetic Losses

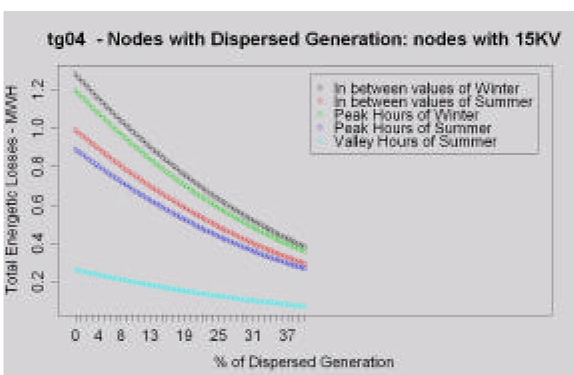

Fig. 18. RMV Network – Energetic Losses

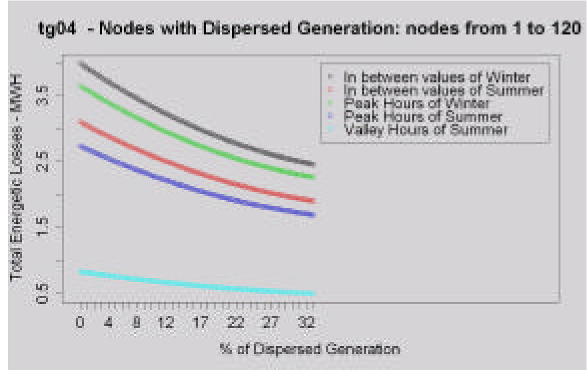

Fig. 19. SUMV Network. Energetic Losses

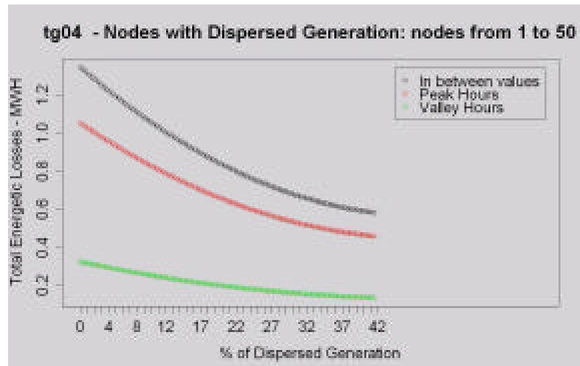

Fig. 20 – UMV Network. Energetic Losses

E. Branches Congestion Impact

The following graphs show the networks branches load variation, for the load tg $\phi = 0.4$ scenarios, as a function of the micro generation level penetration.

It was observed that as larger is the micro generation integration percentage the smaller is the load in the branch.

The following graphs show the load reduction in branch 1–3 for different dispersed generation penetration levels. This branch was chosen because it has a higher load before reducing the active power in load node.

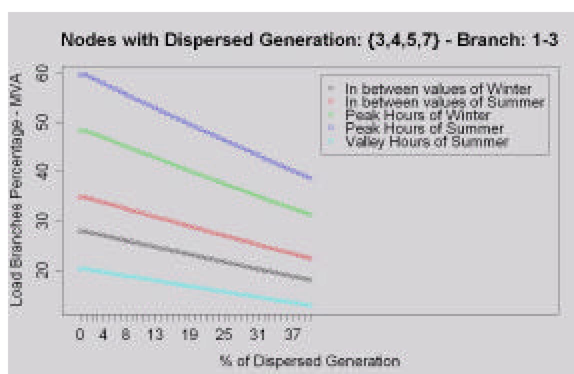

Fig. 21. HV Network – Load Branches

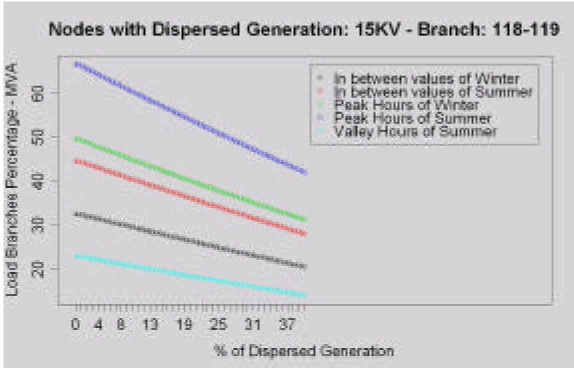

Fig. 22. RMV Network – Load Branches

The previous graphs show the load reduction in 118–119 branch for different dispersed generation penetration. This branch was chosen because it has a higher load before reducing the Active Power in each node with 15 KV.

The following graphs show the load reduction in 7-12 branch for different dispersed generation penetration. This branch was chosen because it has a higher load before reducing the Active Power in each node from 1 to 120.

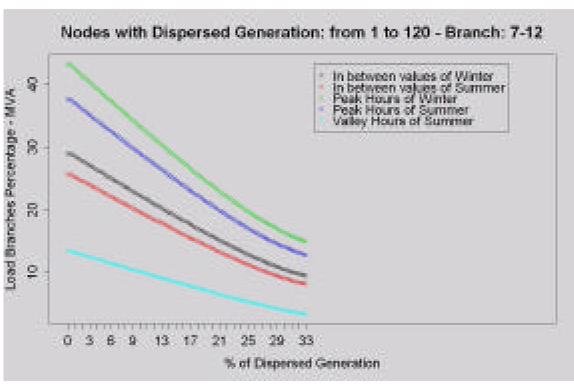

Fig. 23. SUMV Network – Load Branches

The following graphs show the load reduction in 94–95 branch for different dispersed generation values. This branch was chosen because it has a higher load before reducing the Active Power in each node from 1 to 50.

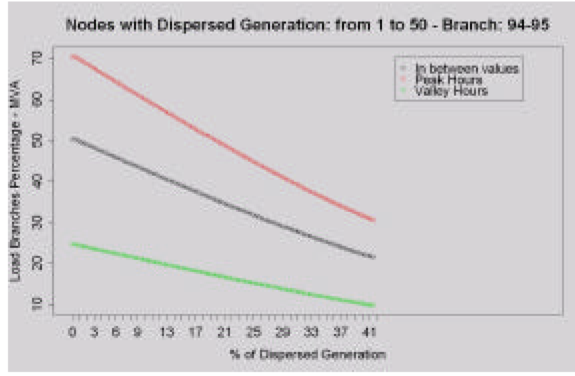

Fig. 24. UMV Network – Load Branches

5. Conclusion

The main objective of this work is analysing the dispersed generation impact in distribution networks. For that, the voltages profiles variations, losses and branches congestion variations are calculated in function of dispersed generation penetration.

The dispersed generation contribution was simulated by means of a decrease in the active power consumed in a set of selected nodes in different networks (High Voltage, Rural Medium Voltage, Medium Semi-Urban Voltage and Urban Medium Voltage). The nodes were selected randomly and the Active Power decrease was performed homogeneously.

The results show that the dispersed generation increase brings some vantages to the distribution systems exploration. It is shown that the voltage values grow linearly with the distributed generation. On the other hand, the Active, Reactive and Energy losses decrease with the growth of distributed production penetration.

References

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