A new approach of intelligent control voltage on the low side voltage of distribution transformers based on electrical equivalent model of the system

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Abstract — The aim of this paper is to present the problems involved in the control of voltage on the low voltage side of distribution transformers. As proposed for the dealings of this problem is made the presentation of an architecture for the intelligent automatic control of voltage. The goal with this design is to provide grants to set up a system for regulating the voltage on the low side which is technically and economically feasible to be deployed where conventional solutions, with the inclusion of line regulators, are not.

Key-words — Voltage regulation, power quality, electricity distribution, intelligent systems, electrical equivalent model.

I. INTRODUCTION

Voltage regulation in the context of low voltage power distribution is an open problem given that existing solutions to keep the voltage within predefined parameters are often less than optimal as possible. In addition, there is the need for constant refinement on the basis of the regulatory aspects of the Brazilian electricity sector. Thus, it is in this context that we observe a search for alternatives to make the control voltage is able to meet the following requirements:

a) Maintaining voltage within the range considered adequate;
b) Be technically and economically feasible;
c) Do not degrade the quality indices of the supply of electricity in the distribution system in which it operates.

Based on conventional approaches to regulating voltage employed in the distribution system, the aspects quoted above can not be fully met. For conventional approach is cited voltage control for switching transformers tap's and voltage regulators line. Both alternatives perform tension control of the medium voltage.

Thus, in that paper will be made a statistical analysis of actual data measurement in order to define a complementary approach to conventional techniques in order to overcome. Therefore, this paper is organized having in Section II a brief summary of techniques reported in the technical literature and could consubstantiate the formulation of a proposal with the desired characteristics. In Section III regulatory issues regarding voltage power supply in Brazil are highlighted. Section IV presents the results obtained with the statistical processing of actual data and, finally, in Section V conclusions and alternatives for better voltage regulation of distribution systems are the subject of.

II. NON-CONVENTIONAL APPROACHES FOR REGULATING VOLTAGE DISTRIBUTION SYSTEMS

Few tools are proposed technical and scientific literature dealing with the subject of the voltage regulation in the low voltage distribution systems. However, the consensus is the need to seek increasingly innovative techniques to solve the problem. Guided by this aspect of this section is conducted.

Conventional methods of voltage regulation follow routines empirically tested and do not take into account the dynamics of the network load as pointed out in [1]. The increasing integration of distributed generation, just to cite one example, makes the dynamics of the system, and consequently, its tension, is difficult to estimate. Thus, in [1] is used the method of Monte Carlo simulation to estimate the levels of regulation of secondary distribution networks, considering the strong presence of distributed generation. This tool is used for statistical processing of information and is subject to combinatorial explosion when the search space is very large. Thus, the adoption of this type of tool in large system, such as the Brazilian electric system, has an important deterrent.

Many studies consider distributed generation, connected directly to the secondary network as a tool to assist in voltage control. On the other hand, the presence of generators can compromise the voltage control, especially in conditions where such devices do not operate with constant power factor or reactive power flow constant [2]. In [3] considers the impact of distributed generation photovoltaic cells as the quality aspects of the electric power supply.

Thus, it has been distributed generation to an important aspect of the regulatory voltage networks not only primary
but also secondary ones, mainly due to the penetration of such generators. However, it has regulatory terms of the Brazilian electric utilities have to rely on alternative suitable for this task and not rely on disparate sources.

In [4] this issue is reinforced, because it shows that the greatest difficulties involving the regulation voltage in secondary distribution networks with presence of distributed generation are given to the fact of the extreme difficulty in estimating the transgressions in voltage limits observed by customers mainly due to the absence of meters.

Often, the improvement in voltage regulation of the secondary distribution is achieved through actions in primary network, as is the case of [5, 6] using intelligent tools.

Among the research lines of equipment to improve the voltage profile in the secondary networks can highlight the application of inverters connected to the distribution network, as is the case of the proposal presented in [7, 8], where the authors used this device as an active power filter, minimizing the zero sequence currents caused by the imbalance of the network.

They are also used in order to improve the quality of distributed energy consumers the static synchronous compensators or STATCOM. In [9] the authors present a proposal of a STATCOM for distribution that provided good results for the regulation of the secondary network, however this proposal is financially costly due to the power electronics needed to operate the device.

In [10] has a proposal that uses the concept of AC-AC converters that act directly on the secondary distribution network, but only monitor the regulatory limits superior and inferior, not optimally exploiting the range of operation voltage.

### III. Regulatory issues related to voltage electric power supply

In the ANEEL Distribution Procedures, more specifically in Module 8 are defined the classification criteria the supply voltage. In Fig 1 is present a summary of that classification to the systems with a nominal voltage of 127 V/220 V

![Voltage range to be observed in customers](image)

Fig. 1 – Operating ranges for nominal voltage of 127/220 V.

From Figure 1 it can be seen that the range considered suitable for 127 V varies between 116 V and 133 V to 220 V and the corresponding ranges between 201 V and 231 V. Outside the range considered adequate, the concessionaire shall be monitored in time of transgression, both critical voltage, and for precarious voltage.

Considering the individual indicators for voltage is precarious DRP is the index of relative duration of transgression to precarious voltage, defined as in (1). Already the DRC is the index of relative duration of transgression for critical voltage, defined in (2).

\[
DRP = \frac{nlp}{1008} \times 100[\%]
\]  
\[
DRC = \frac{nlc}{1008} \times 100[\%]
\]

where nlp is the number of readings in the range of precarious voltage and nlc is the number of readings of voltage for the voltage range-critical. The transgressions are so clearly subject to review in accordance with the temporal ranges transgressed.

The value of the Relative Maximum Duration of Transgression Precarious Voltage - DRPM is set at 3.0%. The value of the Relative Maximum Duration of Transgression Critical Voltage - DRCM is set at 0.5%.

If voltage measurements for complaint and or sample, indicating the amount of DRP DRPM higher than 3%, the distributor should take action to regularize voltage service, within 90 days.

If voltage measurements for complaint and or sample, indicating the amount of DRC higher than 0.5% of the DRCM, the distribution company should take action to regularize voltage service, within 15 days.

Have elapsed the normal deadline for regularization of non-compliance, not been regularized voltage levels in existing deadlines, the distributor must compensate the consumer units that have been subjected to voltages service with transgression of indicators DRP or DRC and those served by the same point connection.

Due to the existing legislation be quite detailed in terms of costs to the dealership if transgressions will be possible to establish criteria that quantify the costs for installation of transformers with intelligent regulation voltage range.

### IV. Statistical analysis of voltage data

A 8334 records were analyzed for low voltage consumers. The analysis covered the period from 2007 to 2012. These records were analyzed, minimum, and maximum values as a function of the mass of data, a statistical approach was adopted. Figure 2 presents a simplified schematic are represented as a low voltage consumers, as well as the origin of the measurements.

Figure 3 shows that 40% of the measurements were below the minimum voltage of 116V, and 20% of the maximum voltage measurements was above 133V. This result shows how the alternative voltage regulation at low voltage has broadly applicable across the industry distribution. Moreover, not only the problem of undervoltage be attacked but also has the possibility of addressing voltages.
Another review is available in Figure 4, showed that 0.4% of consumers are permanently under voltage, while 0.3% of consumers are in permanent overvoltages.

Fig. 2 – Simplified diagram depicting the origin of measurements.

Fig. 3 – Cumulative probability density function.

Fig. 4 – Evaluation summary of measurement campaigns.

Analyzes were also carried out measurements on distribution transformers with reactive compensation at low voltage. The rated power of the transformer rated power and reactive compensation were as follows:

a) 75 kVA + 15 kvar
b) 45 kVA + 7.5 kvar
c) 45 kVA + 0 kvar

The results may be given in Figures 5 through 9.

From Figure 9 we can see that for each 1% change in secondary voltage distribution transformer can have 7% of the minimum voltage, 4% of the average voltage and 3% of the maximum voltage.
V. CONCLUSIONS

In the results presented in that paper is possible to contemplate that only a minority of consumers is constantly undervoltage or overvoltage constant. Consumers who own transgression in supply voltage are not in this condition 100% of the time.

This observation allows us to affirm that the alternative solution for these conditions transgression requires monitoring and active control voltage.

Further, it is possible to check by means of Figure 6 to Figure 8 the voltage at the point of common coupling varies, among other quantities, depending on the load current. Thus, an approach to better control voltage range must make use of information not only tension but also current. Thus it will be possible to have an estimate of the parametric distribution system in the direction of the source, as well as making a compensation of voltage drop in the PAC.

Finally, based on the results provided by Figure 9 can make an estimate of the voltage at the load as a function of the voltage on the low voltage distribution transformer.

REFERENCES


