HYBRID FORECASTING TECHNIQUES APPLIED TO DISTRIBUTION SYSTEMS FOR PROACTIVE VOLTAGE CONTROL

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ABSTRACT

The concept of smart grids make a revolution on the form of operate electrical system. Among the consequences will change the behavior of electricity customers. Regulatory agencies increase their requirements for power quality indices. Thus, the electric utility will seek new alternatives to act in this scenario. In this sense, this paper present a Hybrid Methodology for Forecasts of Electrical Quantities (HMFEQ), that provides new alternatives to the proactive control of VOLT/VAR. The obtained results for application of HMFEQ in one distribution system with one Distributed Generation (DG) are satisfactory.

INTRODUCTION

The complexity of the operation of the Electric Power Systems (EPS) is growing, as well as the necessity of optimization of the energetic resources. On the other hand, the technological revolution that allows innovative solutions, mainly through the tools based on the computational intelligence. In operational terms, considers up that EPS is in conditions of normality. Always of the evaluation parameters related to: frequency, stability, loading and voltage control are set on admissible bands.

In front of the actual technology evolution, the corrective actions, always that is possible, have to be replaced by the proactive actions. For this, is necessary that the dynamic operation of the EPS recurs to the advanced solutions, which consider the forecast resources of quantity electrical Generally, the voltage is a quantity that is explained by the difference of potential between two or more elements of a circuit, however to the operation control in the systems of transmission and distribution is necessary to explore many features related to the behavior of that quantity.

The voltage drop along the feeders is related to the circulation of electric current, therefore the potency that corresponds to the loading of an electrical system in a determined instant. Beyond of the load, the behavior of the voltage is related to the reactive flow.

The research showed in this paper focus on the forecast in the short term, on the horizon of 10 minutes. In addition to predict values the methodology proposed present alternatives to the decision making about proactive actions that reduce the transgressions of the appropriate voltage ranges, by consequent, avoid infringement of regulated indicators and fine reductions.n this context, the present paper shows News alternatives to the control of VOLT/VAR considering the proactive actions based in HMFEQ.

QUANTITIES FORECAST AND THE VOLTAGE CONTROL

The future knowledge by times is treated whit superstition, however in the areas of exact sciences the forecast information are used to optimize processes. In scope of Advanced Metering Infrastructure (AMI), Outage Management System (OMS) and Active Distribution Systems Management (ADMS) it's possible to operate proactively. Currently the obtained information by the system of control and data acquisition (SCADA) are important, and whit the implantation of the Smart Grids will occur changes on the form to plan and operate the distribution system [1-2].

In this way it's important the realization of innovative studies that allows realize quantities forecasts whit this new model in the electric sector, actually that is important the estimate to the take of decisions in several segments of the distribution system [3-4].

The Figure 1 illustrate the possibilities of applications of the forecast and shows the main elements of the chain related to the forecast of quantities, consequently the aspect of energy quality trough forecast of voltage related to the possibilities of operate about control devices.

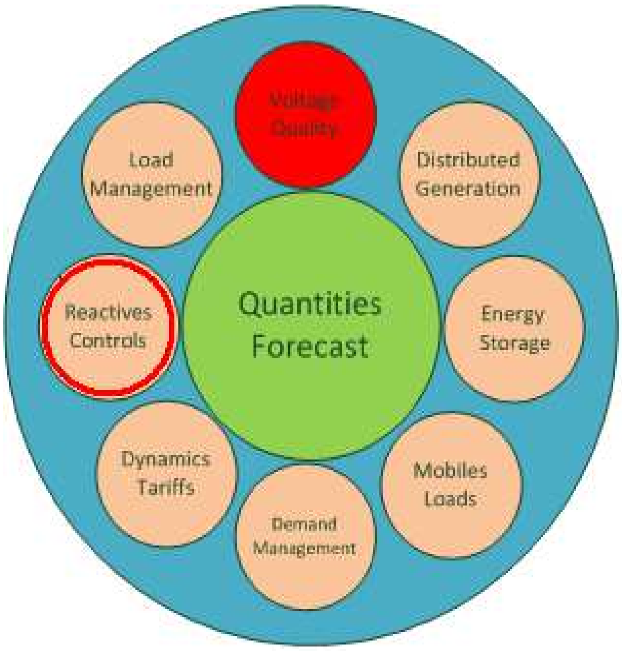

Figure 1 - Elements related to the alternative forecast

In Brazil occurred regulatory alterations referred to the new tariffs modalities, smart meters standard, rules to compensation the energy derived of generation distributed and adequations in the norming of energy qualities. About the quality, the main change occur with the register of transgressions of voltages in form of continuous measurement [5-6-7].

In front of this set of events is appropriate search alternatives to operate proactively, so that if the voltage are out of the adequate ranges the distributer will have to compensate the consumer through fine on the invoice [8-9-10].

On the other hand, the voltage control in the EPS of Brazil is a very complex function, due to the specific aspects as the large geographical dimension of the country. Among the features stands out:

a) Long transmission lines and sub transmission lines;
b) Multiplicity of nominal voltage levels;
c) Seasonal loads over the year;
d) Accentuated transition between the load steps;
e) Predominantly radial configuration in distribution networks.

The importance of the voltage control in the distribution systems is evidenced by the features as:

a) Has specific regulatory;
b) Uses equipment dedicated to their control;
c) Allows correlation whit others variables;
d) Can be analyzed in by time relation.

The actions to the voltage control must include:

a) Actuations of LTC (rele 90);
b) Voltage Regulators (step voltage regulators);
c) TAP adjustment distribution transformers;
d) Switching of capacitors and reactors;
e) Conection of distribuited energy store;
f) Dispatch of Distributed Generation (DG);
g) Redispatch loads;
h) Load Restrictions;
i) Relocation of loads.

Among the applications of the HMFEQ is the control of VOLT/VAR applicable in many situations as:

1. Fulfill energy management goals, as in cases of rationing and contracts of Conservation Voltage Reduction (CVR);

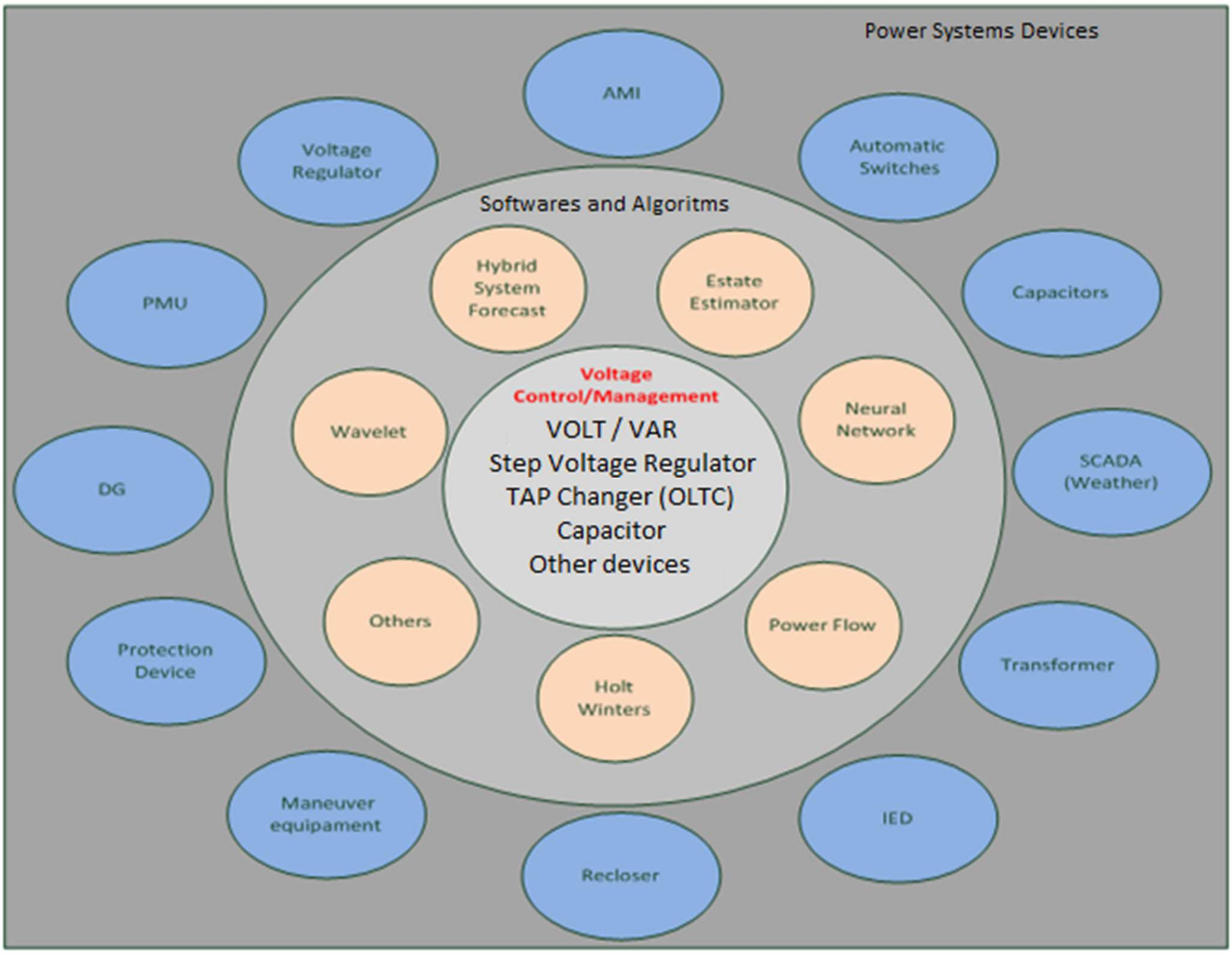

Figure 2 – Interaction with the forecast of the electric system assets.

2. Increase billing, in situations allowed to distributors, by raising the voltage according to the impedance characteristics of loads, model "ZIP";
3. Get energy efficiency through operation system with optimized power flow, voltage level adjusted to the profile of the load and reactive compensation along the feeder;
4. Fulfill the regulations of the electricity sector by operating within the limits of the regulated range, considering the critical points as extreme feeders;
5. Operate the system with high power factor, as it considers the weather issues and the load variations;
6. Integrate distributed generation and storage resources distributed power to the VOLT/VAR control, so together with the dispatch and disconnection, considering the system stability issues and power quality;
7. Identify abnormal situations that can cause physical damage to facilities such as equipment malfunction.

EPS MONITORING

Currently the monitoring of the main quantities in the substations and measurement systems to the billing is a reality, although it is necessary to the advance in the introduction of the technologies, as the use of Phasor Measurement Units (PMU) and the integration of the Intelligent Electronic Devices (IEDs) and smart metering [10-11].
The Figure 2 highlight the layers related to the information obtained of the assets of the distribution system, the resources related to the techniques forecast and the principals elements applied in control VOLT/VAR. Therefore, there is an advance in the initial stand-alone model to the centralized control, and for last the integrated control [8-11].
The HMFEQ showed can be adapted to application in others configurations of the electrical system, however, in this paper are showed alternatives for the voltage control in the permanent regime, with focus in feeders with radial configuration, directing the proactive actions of the operation means based on the forecast of the voltage and active power for the control VOLT/VAR.

FORECAST METHODOLOGY

With base in the current technical literature, is recommended that the search be realized not by the best forecast method, but for combined use of different techniques [12-13].
In the studies realized we obtained satisfactory results referred to the level of precision of the forecast, mainly in the methods combination, so then, hybrid methodology based in the utilization of three distinct techniques.
The purpose of this methodology is combine resources already used in the electric sector, but with differentiated functionalities. In the same way, applies the power flow calculations and estimation of states, both allies the techniques of Artificial Intelligence and Statistical Models.
The direction of flow of other information are entered as the registration of the equipment in the Distribution Management System (DMS) correlated with Geographic Information Systems (GIS).
From the data available on ADMS intends HMFEQ to combine different forecasting techniques, consider power flow calculations, use the state estimators information and use online records SCADA.
The data used as input variables include the main electric quantities: current, voltage, active and reactive power, since the thermal comfort is usually represented by temperature. Because they are phenomena related to time, generally the behavior of these quantities is analyzed in the form of time series.
Based on literature review, this article forecasting quantities was performed for the very short term from three different techniques: Neural Network applicant NARX, Holt-Winters and Neurofuzzy [12-13-14].
The exponential smoothing models Holt-Winters are performed to explain the behavior of the time series and to forecast periods ahead. This model is estimated seasonal factors, the level and trend and is based on three equations using the constant α (alpha), β (beta), and γ (gamma), the constants vary between 0 and 1.
To perform the simulations relating to the forecast by the Neurofuzy has been developed an adaptive inference system by ANFIS function of the Matlab, which is equipped with a training algorithm based on the Sugeno type controller architecture. From the input and output variables is done the training process, which considers fuzzy rules and membership functions to create and adjust the set of rules that enable the forecast.
Among the RNAs, the applicant's type networks stands out for its characteristics of feedback loops because they allow the flow of activation signals and neural output between neurons and may be of different layers of the same layer, or to himself. The supervised learning examines the output data, ie a desired output is informed (target) to the neural network, this is compared to output provided by the method. The task of training is to adjust the weights between neurons so that the output is desired. The forecasts in this work using this type of learning applied to RNA NARX.
The innovation of this methodology is the direct forecast of the quantity voltage and reactive power for certain monitoring points EPS.
The result is based on the technical principles of load forecasting traditionally adopted for operation of electrical systems.
The Figure 3 shows a flowchart regarding the most appropriate choice of technique for HMFEQ.
In this paper, the technique chosen was based on the relative error calculated by Equation 1 based on the last sample, but other combinations can be adopted as the application of HMFEQ.

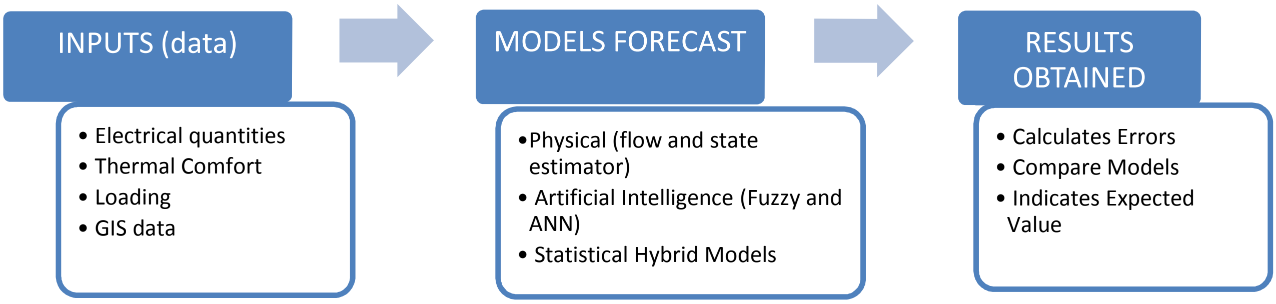

Figure 3 – Flowchart of steps for HMFEQ.

$$Error = \frac{U_{(t-10)} - U_{(t)}}{100} \quad (1)$$

$U_{(t-10)}$: Forecast voltage value of the last sample.
$U_{(t)}$: Real voltage value of the last sample.

Besides the voltage reference point itself, the methodology present in this paper proposes the use of HMFEQ to know in advance the voltage level in different parts of the system, as shown in Figure 4.

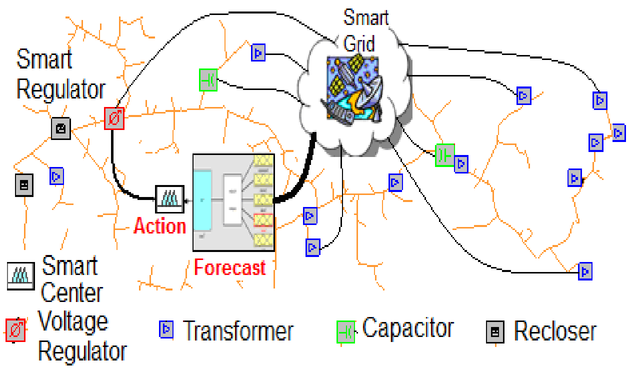

Figure 4 - Smart Voltage Control in the ADMS.

CASE STUDY WITH HMFEQ

To validate the methodology, actual data were used in an electricity distribution company in southern Brazil. The feeder in question is set in the radial form, predominantly rural load and has a Small Hydro Power connection as DG. Figure 5 shows the main asset of the feeder used in the study of application of HMFEQ.

Other feeder data are listed below:

a) Small Hydro Power with two generating units of 1.25 MW each;
b) Demand hired in 2MW connection point;
c) 329 km of medium voltage network in 23kV and 94 km in 13,2kV;
d) A step-down transformer unit;
e) A step-down transformer unit;
f) 756 transformers with 205 km of low voltage.

The power flow calculations and the states of the system equipment were identified by the software used by the utilities for studies in continuous operation.

The feeder in question, the main problem in the VOLT/VAR control is in reactive compensation.

It is therefore proposed the application of HMFEQ to indicate the need for injection of reactive, with the purpose of Small Hydro Power perform this action. This measure indicates the opportunity of GD agents act as providers of "ancillary services" to the distribution system, whose order may be based on the reference values given by HMFEQ.

In Brazil there is still no regulatory act for this feature, but based on these studies, the operational agreements between agents for the supply of reactive will be reviewed.

The amounts are restricted to the limits that do not interfere with the ability of the plant, to provide active power, which is its main objective.

The predicted values are combined in order to be adopted the best forecast for each sample, thus the results obtained in the study are satisfactory.

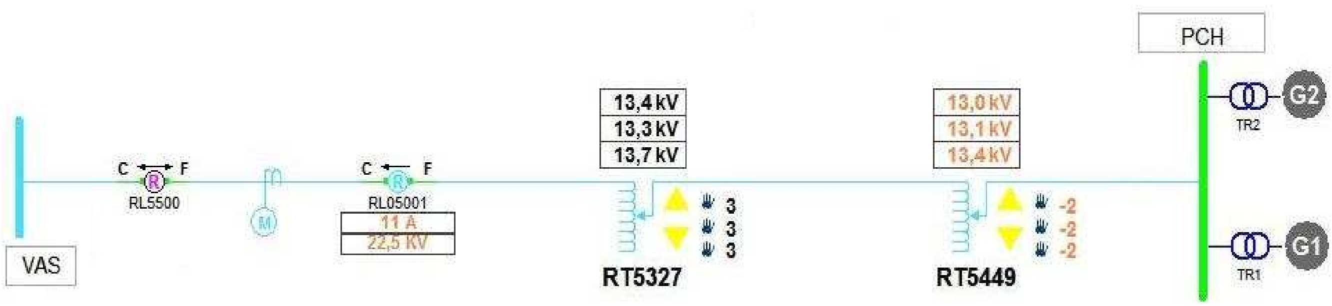

Figure 5 – Feeder for HMFEQ application

The differential application of the methodology hybrid is evidenced in the values presented in Table I and II.

TABLE I. RESULTS OBTAINED FOR VOLT ON THE HORIZON OF 10 MINUTES FOR HMFEQ

Average error	HW	NF	RNA	HYBRID
Training	0,374%	0,578%	0,735%	0,172%
Test	0,482%	0,428%	0,793%	0,186%

TABLE II. RESULTS OBTAINED FOR VAR ON THE HORIZON OF 10 MINUTES FOR HMFEQ

Average error	HW	NF	RNA	HYBRID
Training	6,143%	2,500%	1,411%	0,605%
Test	5,355%	2,800%	1,657%	0,785%

Another application of HMFEQ, this feeder is the optimization of the number of operations of the two voltage regulators. In this sense, the purpose is to make a comparison between the local control and centralized control. The results obtained so far are simulations, but in the future it is proposed to expand the study by HMFEQ, integrated into the supervisory system.

When the Small Hydro Power is inoperative in peak time the distributor is subject to overtaking the hired demand. With the possibility of centralized control combined with HMFEQ you can perform actions to reduce consumption, based on the principle of CVR.

The possibility to optimize the voltage profile is an important factor to prevent transgressions of regulated limits. At minimum load level attention turns to high voltage, since the heavy load step, the focus is on the low voltage feeder extremes.

CONCLUSIONS

Concluded that the quantities forecast on the distribution systems is an important theme to be researched, once that the evolution of the monitoring resources of the distribution systems allows the form of using these online information.

The methodology presented in the paper aligns with the concept of Smart Grids and resource optimization process by which agents of the Electric Sector are submitted.

HMFEQ provides important information for self-healing actions, scheduling of distributed energy sources (DG), participation of fluctuating loads such as electric vehicles, microgrids and energy storage, for example.

It is important to continue research involving HMFEQ, since it allows taking proactive actions that contribute to power quality and optimize the economic assets.

In future applications of HMFEQ, new equipment parameters will be studied. For example the VOLT/VAR control for specific situations of "restart" after fault and self-healing conditions.

Acknowledgments

The authors would like to thank CAPES, CNPq, FAPERGS, CERTAJA and PPGEE/UFSM for technical and financial support to this research.

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