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Voltage Control for Distribution Systems With Inverter-Based Distributed Generators

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ABSTRACT: Recent research indicates that installation of Distributed Generation (DG) devices in the utilities distribution process of a strength network would result in attainment of many likely benefits. However, in the distribution network with a DG the voltage profile upkeep becomes crucial issue. This paper proposes the neo technology depending on the global tips of distribution network is actually used to figure out the management actions of voltage management equipments. At exactly the same time, it attempts to present the ancillary expertise to the DN including voltage regulation, and it tries to reduce DN active energy losses as well as the reactive energy exchanged with the DN by the DG units.

KEYWORDS: Decentralized Generation, Distributed Generation (DG, Optimal Placement of Distributed Generation (OPDG), Distribution Network(DN), photovoltaic systems

I. INTRODUCTION

In the last years the penetration of renewable energy sources (RESs) is growing worldwide encouraged by national and international policies, which aim to increase the share of sustainable sources and highly efficient power units to reduce greenhouse gas emissions and alleviate global warming [1]. However, power quality in existing power systems could worsen because of the high penetration of RESs, which could cause unexpected voltage rises on the distribution lines. In the context of SmartGrid, based on active/autonomous distribution networks and/or multiple microgrids, many technologies and control strategies, such as smart inverters and intelligent distribution transformers, can be implemented on distribution systems providing ancillary services for voltage control [2]. In the past, reactive power regulation has been proposed for voltage control at the connection bus by using decentralized approaches, often without any coordination of distributed systems. Nonetheless, it is reasonable to assume that centralized control will typically give more robust and overall better results have dealt with the voltage control problem considering a centralized approach. In particular, in an optimal control voltage method with coordination of distributed installations, such as on load tap changer (OLTC), step voltage regulator (SVR), shunt capacitor (SC), shunt reactor (ShR), and static var compensator (SVC), was proposed. presented a control strategy based on a predictive control idea for online reconfiguration of OLTC voltage set-point in medium voltage (MV) power grids with DG. In a centralized approach to reduce voltage rises in distribution grid in the presence of high DG penetration was discussed. The same approach was used in to provide ancillary services in distribution systems: a centralized control system in real time produces the reference signals to all converters of the DG units in order to control the reactive power injections. Furthermore, it allows partial compensation or elimination of waveform distortions and voltage unbalances either at all system buses or in particular areas with more sensitive loads. Other interesting works focused on ancillary services are described . In particular, Authors deal with new proceduresfor reactive/voltage ancillary services market: the first proposes a minimization of the reactive power payments by distribution system operator (DSO) to independent power producers

(IPPs), power losses, and voltage profile index; the second one addresses voltage control in multimicrogrid systems. The minimization of the losses is also the goal , where an optimal management of the reactive power, supplied by photovoltaic unit inverters, was proposed. A good discussion on the use of operating charts for describing resources availability in ancillary services is reported . Many presented approaches allow DSO to take advantage of ancillary services without consideration of the potential benefits for IPPs. For this reason, we present a smart strategy that offers the mandatory voltage control ancillary service, based on a coordinated control method, able to obtain the maximum allowable active power production for each RES unit owned by the same IPP. It allows avoiding, as much as possible, the DG units disconnections due to the infringement of voltage regulatory limits. This control strategy operates controlling the DGs' reactive/active power exchange with the distribution network and it is based on the cooperation of data transfer between DSO and IPPs. Specifically, DSO communicates power system state to IPP that solves an optimization problem to provide references to RESs in order to avoid voltage constraint violations. The proposed control, thus, reaps the benefits of both approaches: the control strategy is global because involves DSO and IPPs, therefore intrinsically more reliable and comprehensive, but the resolution of the regulation problem to achieve the overall optimum control input is local. Thus, the IPPs, often constrained to offer the ancillary service of voltage regulation to DSO , can maximize, at the same time, the active power production. Its main contributions compared to the literature can be summarized as follows:

1) the approach discussed in this paper takes into account not only the power converter capability curves, but also the limits imposed by national standards;

2)The optimization Technique increases the active power production of IPPs compared to other local controls .

3) in the presence of several DG-RES units the proposed algorithm calculates the set points for each one in order to control the voltage profiles without the necessity of a complete sensitivity analysis;

4) The control proposes a smart strategy that tries to enhance the classical ancillary service related to voltage regulation.

5) the proposed method allows obtaining more benefits in terms of active power maximization compared to other voltage controls reported in literature also in the presence of high DG generation.

II. PROPOSED SYSTEM

An optimization technique aimed at minimizing power losses within the network and voltage deviation with respect to a reference signal is proposed in [5] for photovoltaic systems (PVs) and applied to the single feeder DN presented in [8].

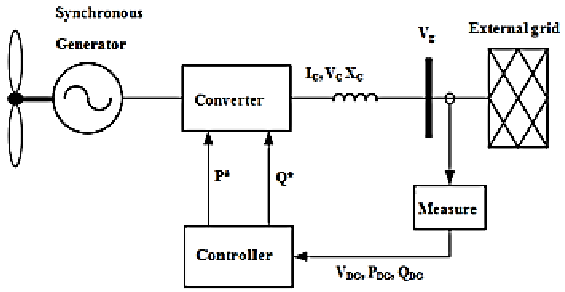

Figure 1: Control System Structure

$P_{DG}=V_{DN}I_{DN}COS\theta$ (1)

$Q_{D}G=(V_{DN}\sin\theta+X_{DN}I_{DN})I_{DN}$ (2)

$P^2_{D}G+Q^2_{DG}\leq(V_{DG}IC)^2$ (3)

For each working point, the boundary of reactive power deviation available for the control action must be contained within the capability curve defined by

$Q_{DG}=\min\{QC_{DG},QV_{DG}\}$ (4)

A. PV Model

Among the various control techniques able to perform voltage regulation, local sensitivity analysis based decentralized control are suitable to regulate voltage profiles with in standard limits. In this paper a decentralized sensitivity based control technique is able to regulate voltage profiles the implemented control strategy allows voltage regulation avoiding, as much as possible, disconnection of DG. The proposed control strategy consists of a local regulation of reactive and active power in to the grid at the DG unit connection bus. The voltage control is realized conducting a sensitivity analysis of the distribution bus voltage with respective to the reactive/active power injections in order to determine the value of sensitivity parameters.

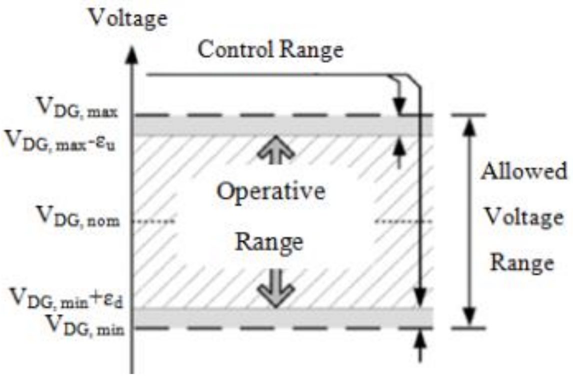

Figure 2: Allowed, operative, and control ranges for the SAB-DC

The control operations begin only if the DG bus voltage level enters the CR, causing a violation of the OR limits. More precisely, when the voltage value enters the CR, a certain amount of reactive and/or active power is injected/absorbed proportionally to the difference between the voltage value within the AR and the threshold value placed between the CR and the OR. The proportionality terms are represented by the sensitivity coefficients as in the equation

$\Delta V^{Q}_{DG}(K)=\Delta Q_{DG}(K)/\rho Q$ ……………….. (5)
$\Delta V^{P}_{DG}(K)=\Delta P_{DG}(K)/\rho P$ ……………… (6)

B. Wind Model

The aerodynamic representation of the turbine blades, generator, and converter are included in this model & simplified. A regular current source is the novel feature in which the regulated current source is represented as a single equivalent source. The rating of an individual wind turbine is considered as the size of a source.The real and reactive power of the generator can be independently controlled by injecting the set of three-phase currents into the grid. A Wind farm of rating 9MW was considered that consisting of six 1.5 MW wind turbines that are connected to a 25 kV distribution system. A doubly-fed induction generator consisting of a wound rotor induction generator is considered in the wind turbines. The stator winding is connected directly to the 50 Hz. The Doubly Fed Induction Generator technology can extract the maximum energy from the wind available for example low wind speeds by controlling the turbine speed, while reducing mechanical efforts on the wind turbine during higher wind speeds. In this paper a speed of 15 m/s is maintained as constant. The Torque controller is used as an control system in order to maintain the speed at 1.2 pu. The reactive power produced by the wind turbine is regulated at 0 Mvar.

III. SIMULATION AND RESULTS

In order to show the effectiveness of the proposed control method a real Italian MV distribution network has been considered. The network, depicted in Fig. 4, is a 54-bus 20-kV distribution system with 4 feeders fed by a 132-kV, 50-Hz sub transmission system with short circuit level of 750 MVA through a 150/20 kV transformer with rated power of ST =25 MVA, Vcc =15.5% and X/R=0.1 [11].. The tap was set to 1.006 p.u., according to one of two classical Italian control strategies for distribution systems[12]. Two different DGs penetration scenarios applied to the DN [13]. Furthermore, the threshold values are set to1 . Time series simulations have been carried out with computed state of 10 minutes in order to illustrate the potential benefits introduced by the proposed controller.

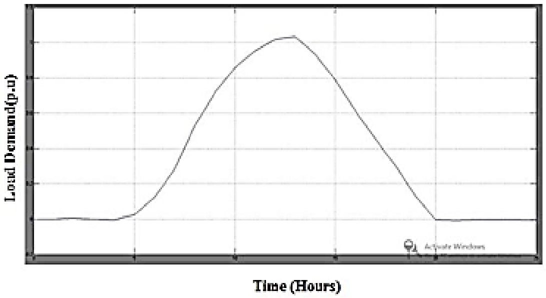

Figure 3: Generation Profiles For Solar

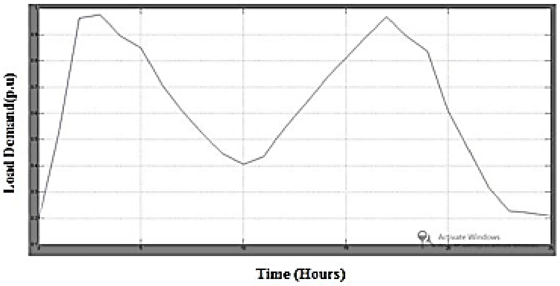

Figure 4: Generation Profiles Wind

The average simulation time to perform the CCM has been estimated around 21 s by using a work station with an Intel Xeon E3-1230 V2 (3.30 GHz, 64 bit) processor, 16 GB of RAM and MATLAB™ R2013a. In any case, it is worth to note that the simulation times for all steps have been less than a minute, which are compatibles with the considered control step time of 10 minutes. However, the convergence times depend on the case study taken into account.

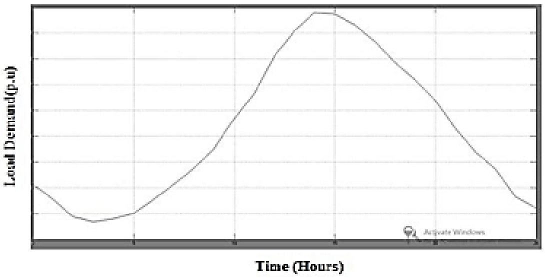

Figure 5: Load demand for Residential loads

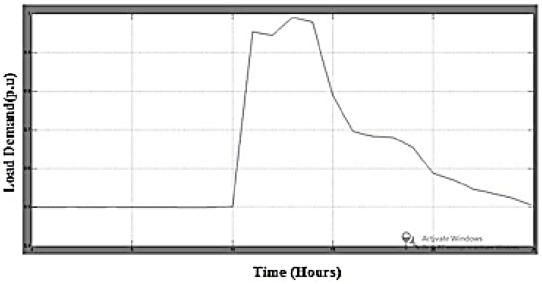

Figure 6: Load demand for Industrial loads

IV. CONCLUSION

This paper has shown the validity of the suggested sensitivity based decentralized control strategy put on to the DN. Simulations carried out on a radial distribution process, have highlighted the great performances of the recommended neighborhood voltage management strategy. Infact, it's apparent that the voltage profiles at buses are actually maintained within regulatory limits. Results received by the enhanced sensitivity analysis based decentralized control program to various DGs scenarios have been proven. Its robustness with respect to unpredicted modifications in model power profiles has been proved through the simulations also. This property allows lowering the correspondence channel reliability requirements which mostly concern only the enhanced thresholds revealing and out ages marketing and sales communications. No constantly detailed data is necessary to carry out the proper management action.

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