Glimpse on Real Time Voltage Control Problems & their Possible Solutions

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Abstract— **Continuously day by day increase in demand of electricity, need of green energy to have better sustainable environment, leads to have an drastic increase in installed capacity of Renewable energy based power generating systems like Photovoltaic, Wind turbines etc. This results in increased penetration of Renewable energy in grid connected systems which further leads to instability. In order to maintain stable operation of grid a robust voltage control method is required. In this paper, various voltage control methods available in literature for grid connected systems are discussed in brief. Real life case studies are also presented in this paper along with solution implemented to overcome those problems. This paper will be helpful to understand the different voltage control problems and their possible solutions.**

Keywords— Case studies, Photovoltaic (PV), Point of Common Coupling (PCC), Voltage Control.

I. RESEARCH PHILOSOPHIES TO CONTROL VOLTAGE

A. ZSI Method

Another method to maintain desired voltage profile at PCC is using Z-Source Inverter (ZSI). Since by calculating the average value of DC-link voltage, input voltage to the inverter can be calculated; DC-link voltage can be used for control of PCC voltage profile. In case DC-link voltage (V_{dc}) is greater than the V_{ref} then the active power reference value will increase which result in decrease in the V_{dc}. This will caused an increase in the inverter current and thus decrease in the $V_{dc.}$ In this manner by virtue of controlling V_{dc} , voltage profile at PCC can be controlled.

B. Sliding Mode Control

To maintain desired voltage profile at PCC; a PWM based Voltage source converter is utilized. Despite of presence of local harmonics generated by loads or grid side harmonic voltage disturbances; Sliding mode control of Voltage source converter ensures to maintain harmonics free desired voltage profile at PCC.

C. Decoupled Method

When the ratio resistance to reactance is greater than 1, then voltage at PCC is sensitive to both reactive power and active power injection. Due to this, both PCC voltage controller and DC-link voltage controller are both dynamically coupled. Thus there is need of decoupling method, so that any change on grid side will not affect the DC-link voltage controller and vice-versa. There are two probable methods for decoupling. First, an algorithm is required to build inside the controller to estimate or measure the reactance. Second method suggests that response time of one controller should be less than the other one, so that there dynamics can be decoupled. A difference of 2-10 times in the controller response time is quit sufficient.

D. Coordinated P-f and Q-V Control

For coordinated real-time balanced control at PCC, based P-f and Q-V drooping relationship, first find the change in load power. According to calculated change in load power, perform economic dispatch analysis and according to that assign power required to be generate by each power generating source present on the generating side.

E. Q(U) Method

Depending upon the voltage of the node under consideration, reactive power Q is injected and thus a close loop control is obtained. Static properties of different loads and different sources are maintained by virtue of close loop control. Figure 1 represents the flowchart of voltage control method through injection of reactive power.

F. Novel Optimal Reactive Power Control Method

To overcome the shortcomings of the Q(U) method i.e. relatively large response time and to optimize the Q(U) method ; a Q(P,U) method is used. From Figure 1 it can be observed that with even small step change in active power, a corresponding reactive power is approximated using cosφ(P) method and then its value is trimmed using Q(U) method.

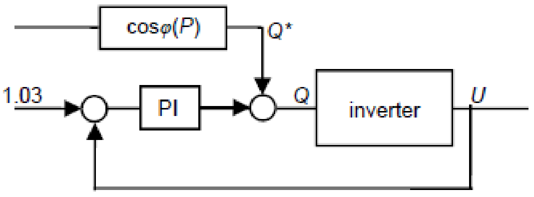

Figure 1 The signal flow graph of Q(P,U) method

Response time of Q(P,U) method is less than Q(U) method and greater than cosφ(P) method. Also steady state error is much smaller than cosφ(P) method.

G. Active/Reactive Power Control

In this method separate active and reactive power controller are used to maintain desired voltage profile at PCC. In case of increased active power, SMES absorbs the excess power whereas in case of increase in reactive power, combination of P.F. and VI will absorb excess reactive power. This method of utilizing both SMES active power controller and P.F-V.I. reactive power controller will enhance the range of voltage control.

II. REPORT ON VARIOUS VOLTAGE CONTROLS FOR PV SYSTEMS

TABLE I CASE STUDIES WITH PROBLEMS & POSSIBLE SOLUTIONS

S. No	Case/Problem Description	Solution Implemented/Investigated
1	Over a past decade countless photovoltaic generators have been set up in the small villages of rural Germany. These PV generators, coupled with simple single or three phase inverters are connected to local grids. The weak grids in these areas often face overvoltage problems during times of light load and high generation especially the afternoon times. This overvoltage causes the distributed generation to trip and interrupts the supply of renewable generation to the grid.	• Solution for Low voltage (LV) The PCS100 AVR LV unit can be installed next to an existing secondary substation, or it can be supplied as an integrated part of a new substation. It is connected in series between the low voltage side of the distribution transformer and the load feeders. Six pilot units have already been installed in various places in Europe in order to correct the utility voltage regulation problems for several major utilities. • Solution for Medium voltage (MV) For medium voltage applications the PCS100 AVR MV unit can be installed in series with the supply. It provides continuous and dynamic voltage correction up to ±10% percent for loads up to 10 MVA and beyond. One pilot unit has been strategically placed in Germany. It regulates the medium voltage of a switching station that supplies feeders to more than 60 secondary substations.
2	Voltage rise in LV networks There have been two recorded instances of significant LV network voltage rises in Carnarvon.	Both these problems have been resolved and the network brought back within acceptable limits by re-configuration of the distribution transformer tap changer or by line augmentations. • Current Scenario: ✓ Rectification of phase imbalance with respect to both loads and PV system connections ✓ Distribution transformer taps setting changes ✓ Load shifting ✓ Network augmentation • Trial: ✓ Voltage regulation technology.
3	The case studies were computed with a distribution network of Fortum Sähkönsiirto Oy in south-west Finland, including wind turbines. Wind turbines are to be connected to the Kasnäs feeder 22 km away from the HV/MV substation. The distribution network in this area is relatively weak, because the length of the Kasnäs feeder was being too long (71 km) and the load being too small. There were considerable restrictions	The proposed system for voltage control is based on local control of a wind power unit and its co-ordination with distribution network voltage control via an HV/MV substation tap changer. A distribution network management system can also be used in place of substation tap changer. The control of the windmill power factor is the first step, i.e. the control of the power factor is continuous and fast. It is based on local voltage in order to maintain voltage within the minimum and maximum limits. The second step is the reduction of power production if voltage

	on network expansions also because of the environmental reasons.	exceeds the maximum limit of voltage. This step is much slower than the first one, thus a short over-voltage does not lead directly to reduction of output power. The purpose of this step is to provide a secure way to maintain an acceptable voltage level at the distribution network and ensure maximum power production throughout the network under varying loading and production conditions.
4	The main area examined in this study was the "Blacktown Solar Cities" area. In this case, the penetration was high (78%) the feeder was quite short and thus had low impedance.	One potential solution to many of the problems encountered with PV is implementing a storage program. Another option, if penetration gets to a certain level on a distribution substation it could be beneficial to install reactive power compensation as well as harmonic filters on the substation. Alternatively to control the voltage rise associated with PV system integration; it is possible to lower the system voltage. This can be done in two ways i.e. by lowering the voltage in individual feeders using the fixed taps at the distribution transformers or by amending current policies and bulk changing the system voltage to be lower. Another recent alternative is the incorporation of reactive power compensation into the inverters. Reactive power compensation works by having an intelligent inverter which is able to dynamically change the level of reactive power supplied by the inverter. This has a similar effect of switching in capacitor banks into the distribution grid. It is theoretically effective in minimizing the voltage variation at the load end of the network as well.
5	Over voltage at PCC for a period of 120 second is created.	The proposed ESS control scheme detects the sudden change of the PV output and initiates the preventive control. The battery charging/discharging amount is adjusted to account for the change in PV generation irrespective of the state the battery is working in, prior to this time instant.
6	A segment of an existing Belgian medium-voltage distribution system is used to study the power quality and voltage stability with different distributed generation (DG) technologies. The system includes one transformer of 14 MVA, 70/10 kV and four cable feeders.	If there is an overvoltage in the system with the synchronous generator, it has to operate with under excitation and to absorb reactive power instead of injecting it into the system.
7	Case Study by International Energy Agency Photovoltaic Power Systems Program for "Overcoming PV Grid Issues In Urban Areas".	SVR (Step voltage regulator) is installed on distribution line (on the Grid side). The SVR is a transformer with an on-load tap changer for regulating the voltage when it gets close to the limit. But the SVR has the following limitations: ✓ Response time is one of the major disadvantages of the SVR. The device is unable to respond to instantaneous voltage change since switching between taps is mechanical. ✓ Tap changer which is a mechanical connection point, has limitations in switching time due to contact erosion. In order to lengthen the replacement period of the device, it is designed not to respond to transient behavior. Another alternative for overcoming the limitations of SVR is the

		use of TVR (Thyristor voltage regulator). TVR is in Demonstration stage and require Installation on Grid side (on distribution line)
8	Location near Carlsbad NM, Germany. • 10 MWDCPV System 3/4 Mile from Substation • Capacity Penetration of Approximately 100% based on peak annual load	Actions taken/recommendations based on study: 1. Less than a mile (3/4 mile) from substation and using 336 ACSR feeder conductors installed (low impedance cables) 2. Additional line protection added to address "desensitized relaying" 3. Voltage supervised reclosing was added to the substation breakers to address potential problems with PV system size. 4. PV developer was asked to regulate their output power factor to a fixed value to address possible voltage issues. 5. Additionally the PV owner was asked to energize the inverters incrementally in order to avoid large voltage steps.
9	Simulations are carried out, for understanding the voltage fluctuation issues in distribution networks with DG. Decentralized voltage control methods on an IEEE 13 bus system were simulated and the results compared.	The control methods tested include the PFC, the on load tap changing control, and the generation curtailment method. • The PFC method is performed by keeping the generator's power factor constant (by varying the reactive power of the generator according to the real power input). This method of voltage control has proven effective to a certain extent, wherein increasing the generator's input power results in high voltage rise. • Operating the DG under OLTC control with two different tap settings, is also found to be capable of mitigating the voltage rise, with the latter operating condition as more effective in managing the rise. • The option of generation curtailment, which is done by reducing input power, is also found effective in mitigating voltage rise, with a reduction of 40% and 50% in the input generation.
10	The existing electrical distribution system in the UK was not designed for connection of local generation. However the number of embedded generator connections to distribution networks in the UK will continue to rise. As a result a number of technical problems exist, including issue of voltage control/ Voltage rise. The integration of Independent generation into an overall network voltage control policy Seven networks were studied ranging from a 200kW connection on a 415V network to a 50MW connection close to a 132/33kV substation.	The results of the studies carried out coupled with practical experience led to the following solutions being proposed: • Co-ordination of generators on the network those are "electrically close". The REC could be made responsible for the coordination of the power output /voltage support required by the network. • Use of semi-conducting devices to control voltage output from generators Equipment has been produced that provides the capability to transmit power from generation to a grid network without affecting the power quality of the receiving network. • Develop commercial measures to encourage RECs to provide suitable connections at lower contributions from the developer. • A mechanism is required so that the REC can receive payment for transport of electricity from a generation site similar to the charge made for transport to consumers. • Review technical codes and recommendations for connection to networks the codes should be reviewed so that due allowance can be given to modern communication methods between the REC control room and the generator systems. • Install higher voltage networks for local generation connection Only low levels of generation.
10	69 bus radial systems considered for study. The substation voltage is 12.66	The coordinated voltage control has been done by controlling reactive power of the DGs and OLTC tap setting operation to

	kV.	mitigate the risk of under voltage/over voltage. This is to maintain the distributed feeder voltage within the permissible limits base on voltage sensitivity analysis to give priority in reactive power control among four generators.
11	A model of an Australian LV distribution feeder in Western Sydney, New South Wales, was used to investigate the applicability of the proposed voltage rise mitigation strategy.	Proposed control method, utilizes the surplus power to charge distributed battery storage devices in order to reduce the amount of active power injected into the grid. Realistic battery models incorporating the non-linear charging and discharging characteristics are used. An intelligent control strategy for charging and discharging operation is developed to make effective use of the available battery capacity.

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