Available online at https://www.gyanvihar.org/researchjournals/ctm_journals.php
SGVU International Journal of Convergence of Technology and Management
E-ISSN: 2455-7528
Vol.9 Issue 1 Page No 66-73
Conference Proceedings-TMRI-2023

Methods and Techniques to Voltage Profile Improvement in Integrated Renewable Power System – A Review

[1]Ashish Dandotia, [2]Mukesh Kumar Gupta
Department of Electrical Engineering, Suresh Gyan Vihar University, Jaipur, India
Email: ashishdandotia@yahoo.co.in, mukeshkr.gupta@mygyanvihar.com

Abstract— Voltage stability is a serious issue in integrated renewable power system, which are continually running at their limitations due to social, political, and environmental factors. System voltage levels alter whenever there is a change in load. Therefore, reactive power consumption increases as voltage levels decreases. The bus voltage drops continuously if the reactive power demand is not satisfied, which has a serious cascade impact on other neighbouring grids. It becomes more crucial to keep the voltage profile within acceptable limit. Several approaches of maintaining the voltage profile in control limit and its benefits and drawbacks are discussed. This review paper discusses secondary voltage control schemes, sensitivity-based control strategies, Control based on structural characteristics of power system, design and location of FACTS devices utilising various optimization algorithms for VAR compensation.

Keywords— Voltage profile, Power system, Reactive power, FACTS, Control strategies

I. INTRODUCTION

In the operation and administration of power systems, reactive power management has emerged as the most difficult task and challenge. The quality of the power supply may suffer due to certain power system features and connected loads. By supplying or absorbing an adequately amount of reactive power, the degradation of voltage drop can be reversed. However, due to limitations like stability restrictions, the majority of high voltage transmission systems are running below their thermal rating [1-4]. On an alternating current power system, voltage is managed by controlling the generation and absorption of reactive power.

Reactive power produced by the ac power source during a quarter cycle is created by a reactor or a capacitor, which stores the power and releases it during the next quarter cycle. In other words, the reactive power oscillates at a frequency equal to double the rated value between the source and the reactor or capacitor. In nature, the majority of loads are inductive, which absorbs reactive power and causes a low lagging power factor [3]. Connecting capacitors with various ratings along the lines can thus be used to compensate the reactive power. This further limit the transfer of reactive power by allowing the voltage at the

Correspondence to: Ashish Dandotia, Department of Electrical Engineering, Suresh Gyan Vihar University, Jaipur
Corresponding author. E-mail addresses: ashishdandotia@yahoo.co.in

receiving end in the transmission end to vary upto 5%. The control of reactive power is known as load compensation, and it is used in ac power systems to enhance the quality of the supply [5]. Primary, secondary, and tertiary levels of voltage regulation are only a few. The first level is made up of generators with automated voltage regulators to protect against a rise in its limitations [6-7]. Having control over the system's voltage is an essential secondary level control objective. Transferring centralised control to the centre of control is what this entails. Therefore, a flawless and comprehensive control and coordination are made possible by this method of control, which leads to

(i) A strong voltage profile and
(ii) Greater utilisation of reactive resources.

The secondary controllers are coordinated at the tertiary level based on cost and safety considerations, and the ideal voltage profile is determined

In order to maintain system security and make the most use of the reactive sources, reactive power and voltage profile management are now crucial due to the development of networks and the diverse situations under which they function. Although system security is adequately protected by the system's extensive interconnections, this fact alone makes system security more challenging when considering voltage regulation. Based on its structure and the location of the generators, this networked system functions differently and has a point of reactive power. As a result, it becomes challenging for the operators to identify issues and their effects in order to take the appropriate action. The customers are always placed distant from the power plants due to economic and environmental restrictions [8]. Additionally, it is not feasible to expand the network, which causes the system to perform more closely to its permitted parameters. Reactive power and the voltage regulation that goes along with it have thus become crucial elements that are crucial to manage. Recent developments in this field have demonstrated how skills are improved with better determination [9-10]]. The steps followed in achieving better voltage profile control are: installation of OLTC transformers, inductor or capacitor, indicators of voltage failure, control to optimize the flow of power, automatic voltage regulator [11].

In this paper 41 papers are reviewed based on the following four control techniques

- Based on sensitivity analysis
- Based on structural characteristics of power system
- Based on secondary voltage control
- Based on modelling and optimal location of facts devices for VAR compensation

II. CONTROL ACTIONS AND OPERATING MEASURES

System design and various control actions and operating measures to prevent voltage collapse are adopted [12-15]

- Switching of shunt capacitors.
- Blocking of tap-changing transformers.
- Re-dispatch of generation.
- Rescheduling of generator and pilot bus voltages.
- Secondary voltage regulation.
- Load shedding.
- Application of the devices to compensate VAR requirement.
- System voltage control and control on VAR output of the generators.
- Managing the tap changing of the transformers.
- To drop the load during under voltage.
- Proper operation of protective devices and their control

III. SENSITIVITY ANALYSIS BASED CONTROL TECHNIQUE

Correspondence to: Ashish Dandotia, Department of Electrical Engineering, Suresh Gyan Vihar University, Jaipur
Corresponding author. E-mail addresses: ashishdandotia@yahoo.co.in

Many authors have worked on this control technique based on sensitivity analysis to control reactive power and regulate voltage profile in the integrated power system, these are given as:
Author developed a way to regulate the voltages of the generators, the tap settings of the transformer, and the variable reactive power resources in order to improve the profile of voltage and decrease system losses [10].

To minimise losses of the network and system performance sensitivity linking dependent and control variable, a strategy based on linear sensitivity relations is being used. Dual linear programming was utilised to determine the best way to alter the control variables while also satisfying the restriction. The size of the step is not limited during the first iteration and was throughout the succeeding iterations [16]. Each cycle included a computation of the power flow. An approach that may increase voltage while decreasing power losses was proposed [22]. The algorithm uses a technique that disregards zigzagging solutions away from the ideal location. Power flow calculations were not included in any of the iterations. By using the load flow equations as the basis for the sensitivity matrix, dependent variables were eliminated. Both techniques require obtaining the whole inverse or partial inverse of the Jacobian matrix in order to calculate the sensitivity matrix, which takes more time, especially for bulk power systems [17].

A method is developed to assess the sensitivity of line losses based on factors such generator voltages, power reserves of VAR sources, and transformer tap settings. To produce the coefficient values, an eigen vector of a transposed Jacobian matrix was employed. Since the complexity of determining the eigen vectors grows with the size of the matrix, this technique does not require the Jacobian matrix inverse, although it may still be challenging [18].

A control strategy is put forth to enhance voltage profile by lowering the total of weighted voltage deviation using a first order gradient approach. It was done using a model of continuous symmetric power flow that was described in rectangular coordinates. Both the computation of the Lagrangian multiplier using an optimization approach and the power flow both employed constant Jacobian matrices. The benefits of this method include the following:

(i)I Lagrangian multiplier estimate is very simple and efficient
(ii) Both the power flow and the Lagrangian multiplier calculations employ a constant Jacobian matrix. Since Jacobian is characterised by voltage changes,
(iii) computation of trivial bus power throughout iterations of power flow [4].

The A system has developed and is skilled at managing voltage. The method of control is based on the sensitivity of the control bus with regard to the bus breaching the boundaries and the margin of control. When this method was compared to the decentralised method, it was found that the decentralised method was less accurate and required fewer voltage control correction steps [19].

An expert approach for voltage improvement under low severe contingencies is described, and the necessary actions are taken to prevent system collapse when large contingencies are taken into account. The necessity of locking OLTC taps for operators is confirmed by the sensitivity for a load voltage change to a modification of the OLTC tap. For investigations on voltage stability, a novel model including variables for both active power and generator reactive power limit was provided [20].

For online evaluation and for more quickly increasing the margin of voltage stability, a neural network-based technique is suggested. In order to estimate and improve the Voltage Stability Margin (VSM), the Voltage Stability Assessment Neural Network (VSANN) is used. The voltage profile of the network, as determined by a phasor measuring device, makes up the VSANN input pattern. Its capacity for VSM

Correspondence to: Ashish Dandotia, Department of Electrical Engineering, Suresh Gyan Vihar University, Jaipur
Corresponding author. E-mail addresses: ashishdandotia@yahoo.co.in

analysis based on sensitivity relying on bus voltage and VAR compensators is one of its standout features. The key benefit of this technique is that VSM may be determined at a given instant simply from knowledge of bus voltages. As a result, the performance of VSANN is unaffected by changes in system topology brought on by outages [7].

focuses on increasing voltage by adjusting the VAR requirement based on the bus's voltage variation and a comparison of theoretical and real VAR values. Different indices that are more able to pinpoint the margin of system stability were used in the stability study, including the Novel Line Stability Index (NLSI), Fast Voltage Stability Index (FVSI), and Line Quality Factor (LQF) [13].

III. STRUCTURAL CHARACTERISTICS BASED CONTROL TECHNIQUES

Most of the problems being faced in power systems can be well solved with an idea of structural relations on various parameters.
The characteristic indices are based on Y admittance matrix partitioning and intrinsic structure. Ideal generators, affinity of generator and influence of construction on generator and load electrical attraction zones have contributed for the indices. The process of locating the new generator may be made simpler with the help of the acquired indices, and the site thus discovered is also distinct. When compared to other generator locations, this one is weakest, has the longest electrical distance, and has the largest potential to provide actual power to the system [12].

showed enhancement of the voltage profile using the circuit theory idea and the partitioning of yads on networks. The placement of the VAR compensators is determined through eigen value decomposition and a partitioned Y-admittance matrix. Buses connected with smallest eigen value have major impact on overall voltage of network on the basis of inversely proportional relation existing between bus voltage and eigen values. Since these buses are the ones that have a higher electrical distance from generators, this exposes the most advantageous sites for distributing VAR compensators. Since load flow procedures comprise the state variables of VAR compensators, the power flow solution may be utilised to select the right compensator size [5].

IV. SECONDARY VOLTAGE CONTROL BASED CONTROL TECHNIQUES

Secondary voltage control during voltage instability based on prior findings in that area. First, studies into primary, decentralised, and centralised secondary voltage regulation are conducted for essential systems when voltage instability occurs. The results show that SVC activation on AVRs achieves a higher stability margin than main voltage control implementation. Pilot bus voltage control is ineffective if the voltage instability has already started. There are two potential Centralized Secondary Voltage Control (CSVC) emergency modes. In the initial strategy, three stages of regulation—each lasting eight seconds—were employed to modify the set points of the generator's automated voltage regulator. This resulted in an early dampening of oscillation. The generator's automated voltage regulator set points, however, were carried out in five smaller stages [2]. investigated the potential for boosting stability margins by coordinating the power system stabilizer's adaptive parameter modification with automatic secondary voltage control. The setpoint of AVR is impacted by control loops like automatic secondary voltage regulation and power system stabiliser, which both effect the same parameter on different grounds. Automatic secondary voltage control causes system to attain steady state with higher margin of stability after a short sequence of regulation steps. As an alternative, system performance was altered with enhanced margin of stability inside current steady state using power system stabiliser parameter adaptive

Correspondence to: Ashish Dandotia, Department of Electrical Engineering, Suresh Gyan Vihar University, Jaipur
Corresponding author. E-mail addresses: ashishdandotia@yahoo.co.in

resetting. Therefore, these two control loops provide a safety buffer for stability in the larger system [21].

Model that is suggested based on sensitivity for cost-effective VAR dispatch in order to keep SVC VAR reserve and keep the voltage profile at the desired level. The elements governing the Static VAR Compensator's controllability include the reference voltage, the static voltage characteristics of the system, the margin of control, and slopes. Critical Static VAR Compensator is that device that is not within the boundaries of control and coordinates the SVC output at various places. It is detected by susceptance increment during compensation [22].

Presented a strategy based on the multi-agent theory for implementing and coordinating SVR systems. Each controller is considered to be a controlling agent, and the technique effectively makes use of a primary voltage controller to maintain voltage throughout both normal and emergency operations. This method's capacity to function in a crisis is its key strength [23].

Provided a technique for managing voltage at a point that is farthest from the power plant that combines joint voltage control with line drop compensation. The necessity of a device for communication just during an interruption and speedier reaction are the highlights. Without the operator's input, the secondary voltage control reference is automatically defined for the following time [24].

VI. TECHNIQUES BASED ON MODELLING AND OPTIMAL LOCATION OF FACTS DEVICES FOR VAR COMPENSATION

Discussed the use of controlled synchronous voltage sources as dynamic compensators and in transmission power flow. When compared to traditional approaches, this implementation exhibits superior characteristic performance and has the capacity to adjust voltage impedance and angle in transmission systems [9]. Additionally, it has the ability to independently operate VAR compensators and directly interchange active power with an AC system. Consequently, a reaction that is effective for diverse dynamic disturbances is provided [25].

When determining how to dispatch reactive power best, one controlling aspect that was taken into consideration was the settings of FACTS devices. Analysis was done to see how this strategy affected the reduction of system losses [26-27].

Static models of the Static Var Compensator (SVC), Thyristor Controlled Phase Angle Regulator (TCPAR), and Thyristor Controlled Series Compensator are used throughout the formulation process (TCSC). Using the sensitivity indices provided, the ideal placement of FACTS devices is discovered. When compared to traditional techniques, formulation of the optimum reactive power dispatch issue using FACTS devices significantly reduces real power loss. Enhancing voltage and reducing actual power losses are two goals of optimal reactive power dispatch (ORPD) with FACTS formulation [28].

Addressed the inverse relationship between voltage magnitude and vehicle acceleration ratio (VAR) in buses with voltage control and their consequent voltage collapse. An index det D' for a specific point of operation serves to verify this [29-30].

Once the location and size of the VAR resources were decided upon, this relationship was tested for all optimal power flow situations. If all D' are greater than zero, the outcome is considered acceptable; otherwise, a new constraint is added to the OPF issue. In order to have correct voltage management, critical voltage from Q_g-V is supplied, and the issue is then worked through to find a brand-new solution [31-32].

To improve the voltage profile, STATCOM control using fuzzy controller architecture has been researched. Because to their inherent time

Correspondence to: Ashish Dandotia, Department of Electrical Engineering, Suresh Gyan Vihar University, Jaipur
Corresponding author. E-mail addresses: ashishdandotia@yahoo.co.in

delay, traditional procedures were not selected. Fuzzy controllers are specifically designed for compensating because of their consistent and quick results for voltage changes. The control system's entire, simultaneous, and continuous design is accomplished using a genetic algorithm [33].

The modeling of FACTS devices such as SVC, TCSC and TCPST [23] and the way they enhance voltage profile [34-37].

Reported on how to include coordinated SVC into the issue of optimal VAR dispatch and examined its impact on lowering system losses and enhancing voltage profile. Local and distant devices can be controlled simultaneously using coordinated SVC [27-28].

The two operating modes are voltage control and VAR control. An indicator of performance was displayed in order to achieve efficacy in VAR optimization together with coordinated SVC over loss reduction and voltage improvement [38-40].

Examined the impact of STATCOM on the voltage profile and the reactive and active power of various buses both before and after the occurrence of the power system failure [41].

VII. CONCLUSION

According to the review, it was found that different methodologies were employed, with some of them branching off from techniques like sensitivity analysis, secondary voltage control, evaluation of voltage stability indices based on network structural characteristics, and placement of VAR compensators in appropriate locations. The examination of the article has provided insight into many issues that are encountered in power systems owing to a lack of voltage management, as well as their remedies for a better Voltage-VAR balance for the system's dependable functioning.

REFERENCES

[1]. Chopade, P.; Bikdash, M.; Kateeb, I.; Kelkar, A.D. Southeastcon, Reactive Power Management and Voltage Control of Large Transmission System Using Svc (Static Var Compensator) 2011 Proceedings of IEEE,

[2]. Dindigul, International Journal of Applied Engineering Research, Volume 2, No.1,2011, Research Article ISSN 09764259

[3]. Dr.V. Kamaraju, (2008), Electrical power Distribution Systems, Third Edition, Overseas Publishers Pvt. Ltd.

[4]. C.L. Wadhwa, (2005), Electrical Power Systems, Sixth Edition, New Age International Publishers.

[5]. T.J.E. Miller, Reactive Power Control in Electric Systems, John Wiley.

[6]. H.Vu, P. Pruvot, C. Launay, Y. Harmand, ”An improved voltage control on Large-Scale Power system”, IEEE Transactions on Power Systems, Vol.11, No.3, August 1996.

[7]. Dragan s. Popovic, “Impact of Secondary Voltage Control on Voltage Stability”, Electric Power Systems Research, 40, pp. 51-62, 1997.

[8]. Preecha Preedavichit, S.C. Srivastava, “Optimal reactive power dispatch considering FACTS devices”, Electric Power Systems Research, 46, pp. 251–257, 1998.

[9]. P.R. Bijwe, D. P. Kothari, J. Nanda and K. S. Lingamurthy, “Optimal voltage control using a constant sensitivity matrix”, Electric Power Systems Research, 11, pp 195-203, 1986.

[10]. Tajudeen H. Sikiru, Adisa A. Jimoh, Yskandar Hamam, John T. Agee and Roger Ceschi, “Voltage profile improvement based on network structural characteristics”, IEEE transactions on power systems, 2012.

[11]. S. U. Bagwan, A. M. Mulla, U. Gudaru, Hardware Circuit Implementation of Static VAR Compensator (SVC) with Thyristor Binary Compensator,

Correspondence to: Ashish Dandotia, Department of Electrical Engineering, Suresh Gyan Vihar University, Jaipur
Corresponding author. E-mail addresses: ashishdandotia@yahoo.co.in

International Electrical Engineering Journal (IEEJ), Vol. 5 (2014) No. 1, pp. 1240-1246.
[12]. A. F. Zobaa, K. A. Nigim, R. C. Bansal, Technology of VAr Compensators for Induction Generator Applications in Wind Energy Conversion Systems, J. Electrical Systems, 2-3 (2006): 172-184
[13]. R.B. Prada, L. J. Souza, L. A. P. Sousa, " The need for a new constraint on Voltage/reactive power studies to ensure proper voltage control", Electrical Power and Energy Systems, 24, pp. 535-540, 2002.
[14]. M. R. Aghamohammadi, S. Hashemi and M. S. Ghazizadeh," A novel approach for improving voltage stability margin by sensitivity analysis of neural network", Proceedings of IPEC, pp. 280-286, October 2010
[15]. Dragan S. Popovic, "Real-time coordination of Secondary Voltage Control and Power System Stabilizer", Electrical Power and Energy Systems, 24, pp. 405-413, 2002.
[16]. www.standards.ieee.org
[17]. [J. Qiu S.M. Shahidehpour "A new approach for minimizing powr losses and improving voltage profile", IEEE Transactions on Power Systems, Vol. PWRS-2, No. 2, May 1987
[18]. Jizhong Zhu, Kwok Cheung, Davis Hwang, and Ali Sadjadpour, "Operation Strategy for Improving Voltage Profile and Reducing System Loss",IEEE Transations on Power Delivery, Vol. 25, No. 1, pp. 390-397, January 2010.
[19]. Tajudeen H. Sikiru , Adisa A. Jimoh, John T. Agee," Inherent structural characteristic indices of power system networks", Electrical Power and Energy Systems 47 pp 218–224, December 2013
[20]. Kulprakash Kumar Singh, Rajeev Kumar and R.C.Jha, "Improvement of Voltage Profile in Smart Grid Using Voltage Sensitivity Approach", IEEE 2012.
[21]. Shenghu Li, Ming Ding, jingjing Wang, Wei Zhang, "Voltage Control capability of SVC with var dispatch and slope setting", Electric Power Systems Research, 79, pp. 818-825, 2009.
[22]. Rui Jovita G. C. da Silva, A. C. Zambroni de Souza, Rafael C. Leme, Dabit Sonoda, "Decentralized Secondary Voltage control using voltage drop comensator among power plants", Electrical Power and Energy Systems, 47, pp. 61-68, 2013.
[23]. S.M. Shahidehpour and N. I. Deeb, "An overview of the reactive power allocation in Electric Power systems", Electric Machines & Power Systems, Volume 18, Issue 6, pp. 495-518, 1990
[24]. Gehao Sheng, Xiuchen Jiang, Dapeng Duan, Guangyu Tu, "Framework and implementation of Secondary Voltage regulation strategy based on multi-agent technology", Electrical Power and Energy Systems, 31, pp. 67-77, 2009.
[25]. [18] S. P. Singh and G. S. Raju, "Sensitivity based expert system for voltage control in power system", Electrical and power and Energy Systems, Vol. 15, No. 3, pp 131-136, October 1993.
[26]. E. Saeidpour, V.S. Parizy, M. Abedi, H. Rastegar, "Complete, Integrated and Simultaneously Design for STATCOM Fuzzy Controller with Variable Length Genetic algorithm for Voltage Profile Improvement", IEEE 2008.
[27]. www.tomsovic.eecs.wsu.edu
[28]. S. D. Naik, M.K. Khedkar and S. S. Bhat, "Improvement of voltage stability by OLTC and shunt compensation in large multibus power system", proceedings of ICIEA, pp. 264-269, July 2012
[29]. S. Rama Iyer, K. Ramachandran, S. Hariharan, "Optimal capacitor allocation in power systems", Computers & Electrical Engineering Vol. 10, No. 4, pp. 247-258, 1983.
[30]. Idris, R. Mohamad; A. Khairuddin, M. W. Mustafa, A. Kalam, "Optimal allocation of multi-type FACTS devices using bees algorithm for ATC enhancement in deregulated power

Correspondence to: Ashish Dandotia, Department of Electrical Engineering, Suresh Gyan Vihar University, Jaipur
Corresponding author. E-mail addresses: ashishdandotia@yahoo.co.in

system", International Review of Electrical Engineering, Part B, Vol. 5 Issue 2, p. 644, March 2010
[31]. Y. Hoseynpoor, T. PirzadehAshraf, Sh. Sajedi, T. Karimi, "Using SVC for Reactive Power Provision in Restructured Reactive Power Market", Australian Journal of Basic and Applied Sciences, 5(6): pp. 996-1010, 2011. ISSN 1991-8178
[32]. F.A.B. Lemos, L. C. Werberich, J. S. Freitas and M. A. da Rosa, "A Strategic for Voltage Coordinated Control to Improve System Operation", Proceedings of Power Tech, vol. 2, September 2001
[33]. M.Arun Bhaskar, C.Subramani, M. Jagdeesh kumar, S. S. Dash, "Voltage profile improvement using FACTS devices: A comparison between SVC, TCSC and TCPST", International conference on advances in recent technologies in communication and computing, pp. 890-892, 2009.
[34]. K.R.C. Mamandur and R.D. Chenoweth, "Optimal Control of Reactive Power Flow for Improvements in Voltage Profiles and for Real Power Losses Minimization", IEEE Trans. P.A.S., Vol. 100, No. 7, pp. 3185- 3193, July 1981.
[35]. S. Elangovan, "New Approach for Real Power Loss Minimization", IEEE Proceedings, Vol. 130, Pt.c, No. 6, pp 295-299, November 1983.
[36]. Bharat Thapa, T. Murali Mohan, "Analysis of Controller Effects of STATCOM on Power System during the Fault Condition", Vol.2 issue 8, IJAIR 2013.
[37]. M. Ilic, X. Liu, G. h u n g, M. Athans, C. Vialas, P. Pruvot, "Improved Secondary and New Tertiary Voltage Control", IEEE PES WM 137-0 PWRS, 1995
[38]. F. Meslier, "Voltage and reactive power control," paper presented in the name of Task Force 39.02, CIGRE 1992.
[39]. S. R., Parikh A. R. Patel, A User-Friendly Simulink Model for FC-TCR to Investigate Power System Issues, IJSRD - International Journal for Scientific Research & Development| Vol. 1, Issue 12, 2014 | ISSN (online): 2321-0613.
[40]. S. Umashankar, K. K. Ray, D. P. Kothari, Dynamic Analysis of Static VAr Compensator for the Evaluation of Reactive Power Compensation, International Journal of Applied Engineering Research; July 2010, Vol. 5 Issue 13, p. 2345.
[41]. http://www.mathworks.com/help/physmod/sps/powersys/ug/thyr istor-based-static-var-compensator.html

Correspondence to: Ashish Dandotia, Department of Electrical Engineering, Suresh Gyan Vihar University, Jaipur
Corresponding author. E-mail addresses: ashishdandotia@yahoo.co.in