Review on Using DVR to Reduce Voltage Sag and Swell in Integrated Distribution System

Ravishankar B S[1], Dr.Mohan.N[1] ,Chandramohan S[2], Raghunand D R[2]
[1]*Faculty in department of Electrical and Electronics Engineering, JSS Science &Technology University,Mysuru*
[2]*UG Scholar, Electrical and Electronic Engineering, JSS Science and Technology University, Mysuru*

Abstract: The electrical power systems generate, transmit, and distribute electrical energy to load centres in a dependable, cost-effective, and efficient way. difficulties with the voltage, harmonics, wiring and grounding, and the load system for switching capacitors. Harmonics in the power distribution system are among the voltage sags and swells that are most severe, and they can be effectively reduced by using a powerful specialised power device called a dynamic voltage restorer (DVR). In order to increase the effectiveness of the PV integrated Distribution system, this research provides a comparative assessment of various control mechanisms employed in DVR.

Keyword-Photovoltaic (PV), Dynamic Voltage Restorer (DVR), Voltage Sag, Voltage Swell

I INTRODUCTION

Present days, the dependent world on non-renewable resources has proven that it is non environmental friendly, costly and could not sustainable for long time. Thus, it requires transient change from non-renewable resources to renewable resources. Among renewable resources PV and windmill are widely used. The use of solar photovoltaic (PV) in integrated system because its free from pollution and available in different sizes. The PV mainly depend on irradiance and temperature. It can be arranged in parallel or series according to the system.[1]. The block diagram of PV integrated distribution system is shown in figure 1.

Equipment malfunctions are the result of voltage and current problems that affect the quality of the power. The most serious problems with the power system at both the transmission and distribution levels are voltage sag and swell. Voltage sag is the term for the drop in rms value of voltage below the nominal voltage that lasts for half a cycle to one minute and ranges from 0.1 to 0.9 pu. short circuit faults brought on by Voltage sag may result from insulation breakdown under extreme load circumstances. Similar to this, a voltage swell is a sudden increase in rms voltage above nominal value that lasts for up to one minute and ranges from 1.1 to 1.8 pu.. Voltage swell can be caused by turning off heavy loads, energising capacitor banks, and other factors [2–7]. The incidence of voltage swell is less common than that of voltage sag.

Custom power devices can be used to solve the aforementioned issues. In 1995, N.G. Hingorani proposed the idea of custom Power. Uninterruptible Power Supply (UPS), Unified Power Quality Conditioner (UPQC), Unified Power Flow Controller (UPFC), and Dynamic Volta are a few examples of the various types of custom power devices used to improve the quality of the power supply. Other examples include Synchronous Compensator (STATCOM), Static Var Compensator (SVC), Distribution Static Synchronous Compensator (DSTATCOM), Battery Energy Storage System (BESS), Surge Arrester(SA)[8].

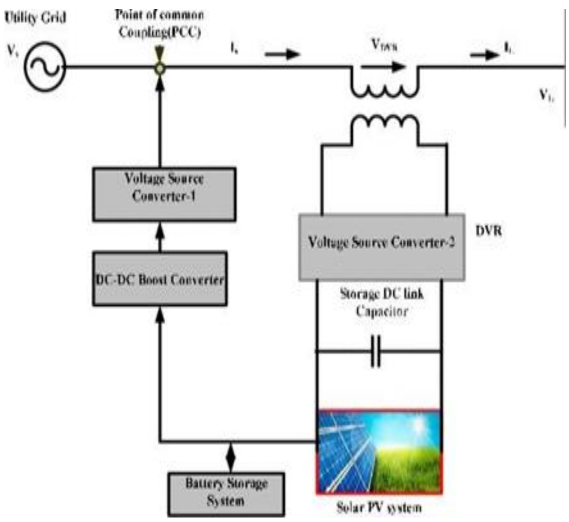

Fig1.Block diagram of PV integrated system

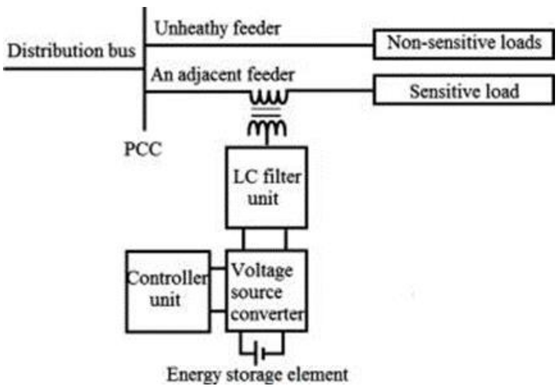

Fig 2. Block Diagram of DVR

We take into account DVR in the aforementioned custom power devices because it is more effective and cost-effective. In a 12.47 kV grid in Anderson, South Carolina, the first DVR was installed in North America in 1996. DVR is more affordable, has a larger energy capacity, is more compact, and has the ability to regulate active power flow. In light of the aforementioned considerations, DVR is the best tailored power solution for reducing voltage sag/swell in PV integrated Distribution System. Furthermore, it is utilised to safeguard delicate loads from numerous power quality problems [9].

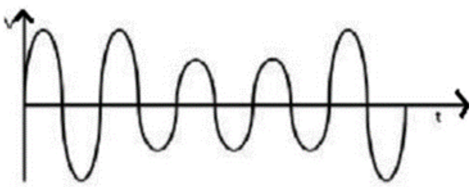

Fig2.Voltage Sag

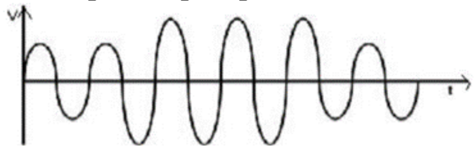

Fig3.Voltage Swell

Dynamic Voltage Restorer (DVR)

A solid-state device called a dynamic voltage restorer is linked in series with the supply and the load. In order to regulate voltage at the voltage end, it injects the missing voltage waveform into the system. It prevents any power interruption in the load by regulating the voltage on the load side thus preventing voltage sag and swell [10-12].

DVR consist of Injection or Booster transformer, Harmonic filter, Voltage Source converter (VSC), DC Energy Storage Device and charging circuit, Control system. The basic principle of DVR is to injects the voltage waveform from the injection transformer to compensate voltage sag/swell. The maximum injection capability of DVR depends on injection transformer ratio and energy storage device ratings.

The DVR injection voltage is

given by

$V_{DVR} = V_{Load} + Z_{line}\ I_{loa} V_{source….1}$

Where

V_{Load} = Desired load voltage

Z_{line} = Line impedance

I_{load} = Load Current

V_{source} = System voltage during any Fault conditions

V_{DVR} =DVR injected Voltage.

II COMPONENTS OF DVR

1.Injection Transformer: Control system will inject the compensating voltage produced by VSC after detecting any disruption in the voltage supply .It will also isolates VSC and Control system in the distribution system.

2.Voltage Source Converter: VSC is made up of storage and switching components that produce compensating voltage of the necessary magnitude and phase. During Voltage sag VSC provides the missing voltage.

3.Harmonic Filter: It keeps the harmonic content within the allowable range.

4.Storage Device: It is employed to provide the necessary power to produce compensatory voltage for the VSC.

5.Control circuit: It continuously monitors the supply voltage, looks for disturbances, compares them to the reference value, and produces compensatory voltage to reduce voltage sag and swell.

There are three different modes of operation [3].

Standby mode: It runs in the typical manner. The voltage that the DVR injects in this mode is zero. In this mode, the injection transformer's secondary winding shorts out, allowing full load current to flow through the primary winding.

Protection mode: The current on the load side exceeds the permitted limit in this mode because of a high inrush current and a short circuit fault on the load. As a result, bypass switches will be used to disconnect the DVR from the system, and a different path for current flow will be established.

Injection mode: To correct for any voltage disturbances, the voltage will be injected in series with the system in this mode.

Methods of Voltage compensation:

There are mainly three voltage compensation Techniquesto overcome power quality issues used in DVR [13-18]:

1.Pre-sag compensation: This technique mainly used for non-linear loads. This approach returns the voltage magnitude and phase angle to their pre-sag values by using DVR to supply the difference between pre-sag and sag voltage.

2.In-phase compensation: This technique mainly used for linear loads. In this method, DVR compensates only for voltage magnitude and that compensated voltage hasthe same phase as that of sagged voltage. Hence, the injected voltage by DVR is minimized.

3.Phase advanced Compensation: It is mostly utilized to reduce active power infusion from the DVR. This technique involves injecting the DVR voltage with a phase advance angle in relation to the sag voltage.

III CONTROL STRATEGIES

DVR is a nonlinear system due to the usage of power electronics devices. Non-linear controllers like Artificial Neural Network (ANN), Fuzzy Logic (FL), Hysteresis controller ,PSVT. The ANN approach can offer increased precision through interpolation since it has the potential to self-organize and learn.

1.Artificial Neural Network:

ANN imitates animal brains, where neurons are interconnected in intricate networks. In an ANN, there are many nodes that function as neurons. As a node receives information, it processes it before passing it on to the next node. Each input is processed via all of the levels in which the nodes are placed before producing an output. Firstly,the power quality issues will be analysed and then the data will be normalized and randomized arounda point which is chosen. Then by back propagationit will assigns weights and biases. With suitable parameters iterations will be done [19]. The mean Squared Error (MSE) will be calculated from the output and checks whether it is below desirable le error value. The iteration will stop and the weights and biases will be changed before moving on to the next layer if the MSE is less than the desired error. In this manner, ANN is able to precisely compute the sag and swell. By injecting or removing power from the line that has power quality difficulties, it can be seen that ANN-based DVR is a reliable network [16–18].

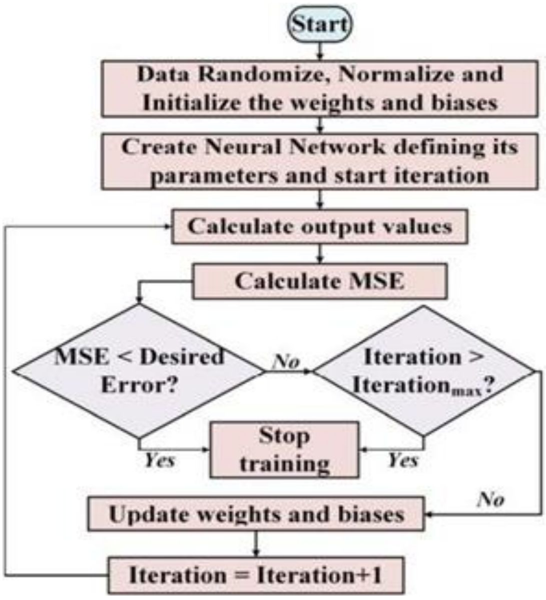

Fig 3. Flow chart for ANN controller for DVR

2.Hysteresis voltage controller:

The difference between the two assertions is used by a voltage controller known as a hysteresis voltage controller to produce a switching signal. The supply voltage and the injection transformer, where the DVR injects the voltage, were the two voltage signals that were required. When the signals are compared, an error signal is generated and sent to a hysteresis switching pattern. There are upper and lower bands.

If the error signal lies between the upper and lower band, there is no switching signal. If the error signal crosses the top band, the switching signal will become weaker and vice versa [19–21].

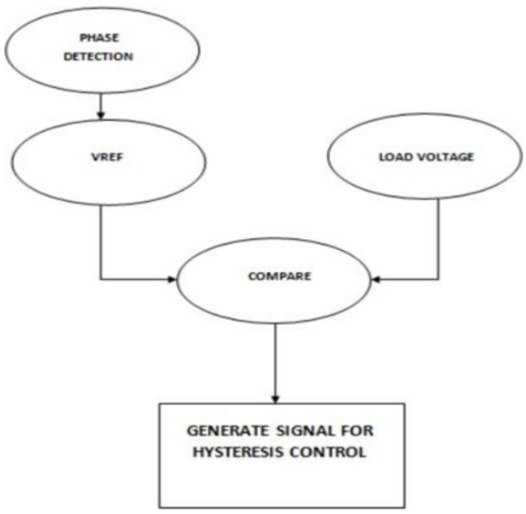

Fig 4. Flow chart for Hysteresis Voltage Controller for DVR

3. Fuzzy Based controller:
The foundation of the fuzzy model is a set of numerical values produced by rules with specified parameters. Fuzzy based controllers are the most effective choice if logical operators need to be able to make judgement calls. Data parameter and rule define parameter are its two dependent variables. These variables are determined by capability. Here, an automatic search is built to order a certain control depending on sagging voltage at the supply point. RMS voltage values are used as input data for the fuzzy control, which uses fuzzy parameters to express them. RMS voltage values are crucial to the fuzzy control because they are used to determine the voltage sagging threshold. The threshold values for the output signal based on the fuzzy specified parameter were determined. For necessary control, output signals may operate on an ON/OFF signal. When the output signal is communicated to the main control, voltage sag will be corrected [22].

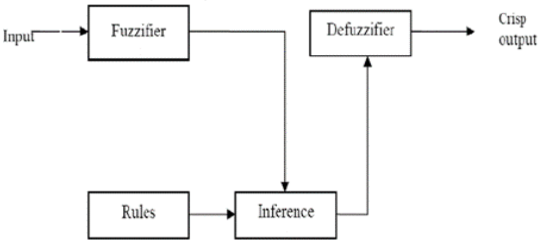

Fig.5 Flowchart for Fuzzy based controller

4.Novel Control theory:
This method generates control pulses for the DVR. This approach senses the system's line voltage and divides it into three phases: V_a, V_b, and V_c. Equations are given for the three error signals V_{ae}, V_{be}, and V_{ce} from each phase to the PWM generator:

V_{ae} =($V_{maxrefa}$ – sqrt($V_\alpha{}^2$ -$V_\beta{}^2$))sin(ωt-0°) ……2

V_{be} =($V_{maxrefb}$ – sqrt($V_\alpha{}^2$ -$V_\beta{}^2$))sin(ωt-120°)….3

V_{ce} =($V_{maxrefc}$ – sqrt($V_\alpha{}^2$ -$V_\beta{}^2$))sin(ωt-240°)…..4

In this control technique, it prevents complicated problematic calculations and the control technique will be simplified. From source voltage, the phase voltage data is obtained and each phase voltage is squared and added to a delay [23]. The resulting signal is square-rooted to produce a resultant signal with the greatest value, which is then compared to a reference value of 1 p.u. The resultant signal, which serves as the reference for the initial phase that was divided, is processed in a phase-locked loop. As a result, this is repeated for any further two phases with a phase difference of 120 degrees. The PWM generator is then used to process the three phase error signals and create control pulses for the DVR's power switches.

5. Predictive Space Vector Transformation (PSVT)
When compared to other controllers based on DVR, VSC generates reactive power that must be adjusted for using a feedback control loop. The other controllers based on DVR are able to handle voltage difficulties. To resolve this problem The distribution system uses a PSVT-based DVR.
PSVT analyses the fluctuation in power on the distribution side and generates the appropriate feedback control. PSVT DVR PSVT with PR controller is utilised here. Predictive current control is a technique used in PR controller. The input current is directly controlled by the PR controller at the time of voltage injection to the grid. PSVT has a closed-loop system that gives the inverter the right feedback signal. This inverter produces a phase sine wave that is in phase with the supply voltage. To compensate for unbalanced and nonlinear loads with significant gains, the controller generates a high order harmonic [23].

Table.1 DVR Control strategies

SL No	Control Strategy	Conculsion
1	ArtificialNeural Network(ANN)	Algorithms are quick and effective. It is capable of reducing THD to the greatest extent. It is commonly used because of its precision..
2	Hysteresis Voltage control	Hysteresis controllers can be used to reduce the three-phase system's fault situation. The voltage quality is improved by adjusting THD since it is the best controller for voltage compensation in defective conditions.
3	Fuzzy Based controller	The fuzzy logic control is best in compensating the performance compared to traditional PI controller. It is effective in damping system oscillations. Transformerless-DVR compensating performance is enhanced.
4	Novel Control Theory	Trigonometric function isreduced. It is less complexity compared to SRF sincemathematical equations used is less. It does not use transformation block. The line voltage is divided into three phases, and the PWM generator receives their error signals.
5	Predictive Space vector Transfor mation (PSVT)	The PWM of the inverter is adjusted using the PSVT controller. to create the proper reactive power and maintain the power quality using the DVR offset.At the time of reactive adjustment to the grid, it reduces THD to 1.06% and compensates for voltage sag and swell.

IV CONCLUSION

In this paper a review about the power quality issues likevoltage sag and swell is discussed. Different control techniques employed in DVR to mitigate voltage sag andvoltage swell is discussed. PSVT is best control technique for reducing THD to 1.06% compared to othertechnique. Fuzzy logic can give a reduced THD and it can also be considered. ANN is the best in reduced energy consumption, fast response. The THD will be 2.83% in ANN based DVR.It requires some time to feedthe data to the ANN, but the drawback can be overcomeby using GPUs. With this in mind, voltage sag and voltage swell in the PV integrated distribution system can be reduced using PSVT and ANN-based DVR.

References/ Published	Contribution
[1] 2022	Operation of DVR with PI controller using Partial Swarm Optimization Technique and Adaptive fuzzy technique with variable loads
[2] 2022	Through the proper placement of DVRs, the non-collocated users have been divided into manageable clusters using the suggested graph-partitioning concept.
[3] 2022	Controlling techniques for DVR and comparison between SRF and Noval Theory
[4] 2021	DVR is used to limit the fault current and to improve the voltage quality at common coupling point
[5] 2021	The most popular interfaces for interconnecting distributed systems, notably for integrating distributed energy sources, active filtering, and power supply applications, are VSC-based converters. This is a result of developments in control strategy development and device material technology.
[9] 2021	To remove low order odd harmonic components found in the output current of VSI and the overall harmonic distortion, the PR controller design is cascaded with a harmonic compensator. (THD).
[13] 2018	Enhancing the capabilities of the DVR's restoration and harmonics suppression using an artificial neural network (ANN)-based controller
[18] 2015	The DVR is intended to safeguard the entire plant from loads up to certain MVA.
[19] 2014	Basic operation of DVR with PLL and Park's Transformation

Table2. Summary

REFRENCE

[1] Saddam Subhi Salman, Abdulrahim Thiab Humod, Fadhil A. Hasan, "Optimum control for dynamic voltage restorer based on particle swarm optimization algorithm". In Indonesian Journal of Electrical Engineering and Computer Science.2022

[2] Subir Majumder, Shrikrishna A. Khaparde, Ashish P, "Graph Theory based Voltage Sag Mitigation Cluster Formation Utilizing Dynamic Voltage Restorers in Radial Distribution NeComponents".2021

[3] Design Approach of Power Electronic-Based Distributed Generation Units Focused on Power-Quality Improvement". Issn No: 2236-6124.2021

[4] 5. Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems. Narain G. Hingorani, Laszlo Gyugyi. Wiley IEEE press.2021

[5] S. Sudharani, D. Godwin IMManuel, "Mitigation of voltage sag/swell by dynamic voltage restorer using fuzzy based particle swarm controller.,2020. doi.org/10.1016 /j.matpr.2020.11.609. 2021

[6] K. Jeyaraj, D. Durairaj, and A. I. S. Velusamy, "Development and performance analysis of PSO-optimized sliding mode controller–based dynamic voltage restorer for power quality enhancement," International Transactions on Electrical Energy Systems, vol. 30, no. 3, pp. 1–14, 2020, doi: 10.1002/2050-7038.12243.

[7] Viswaprakash Babu, K. Shafeeque Ahmed, Y. Mohamed Shuaib, and M. Manikandan, "Power Quality Enhancement Using Dynamic Voltage Restorer (DVR)- Based Predictive Space Vector Transformation (PSVT) With Proportional Resonant (PR)-Controller".2021

[8] Suraya, S., Irshad, S. M., Azeem, M. F., Al-Gahtani, S. F., & Mahammad, M. H. (2020). Multiple Voltage Disturbance Compensation in Distribution Systems using DVR. Engineering, Technology & Applied Science Research, 10(3), 5732-5741.. 2020

[9] Syed Suraya , Shaik Mohammad Irshad, Mohammad Fazle Azeem, Multiple Voltage Disturbance Compensation in Distribution System using DVR.In Engineering, Technology & Applied Science Research.2020.

[10] Arpitha M J, Sowmyashree N, Dr. M S Shashikala, "Power Quality Enhancement using Dynamic Voltage Restorer (DVR) by Artificial Neural Network and Hysteresis Voltage Control Techniques". In Global Conference for Advancement in Technology. 2019

[11] Md. Samiul Haque Sunny, Eklas Hossain, Mikal Ahmed, "Artificial Neural Network based Dynamic Voltage Restorer for Improvement of Power Quality".2018

[12]. T. Sridevi, Y. Suri Babu, "Mitigation of voltage sag and swell in a Grid connected PV system by using Dynamic Voltage Restorer",

April 2018, IJCRT, ISSN: 2320-2882…..2018

[13] Nizamulmuluk, AgungWarsito, Juningtyastuti, Iwan setiawan, "Voltage sag mitigation due to short circuit current using dynamic voltage restorer based on hysteresis controller", ICITACEE, pp. 108-112,2017

[14] Nizamul Muluk, Agung Warsito, Juningtyastuti, Iwan Setiawan, "Voltage Sag Mitigation Due to Short Circuit Current Using Dynamic Voltage Restorer Based on Hysteresis Controller". In Int. Conf. on Information Tech., Computer, and Electrical Engineering (ICITACEE).2017

[15] Ken Weng Kow, Yee Wan Wong, Rajparthiban Kumar Rajkumar, Rajprasad Kumar Rajkumar, "A review on performance of artificial intelligence and conventional method in mitigating PV grid-tied related power quality events". Renewable and Sustainable Energy Reviews.2016

[16] Chatala Lakshmi, Mukiri Anil Prakash, "A Novel Voltage Sag/Swell Compensation using DVR with Distributed Generation Scheme". In International journal of scientific engineering and technology research. ISSN 2319-88852….2015

[17] Deepa Francis, Tomson Thomas, "Mitigation of Voltage Sag and Swell Using Dynamic Voltage Restorer", International Conference on Magnetics, Machines & Drives.2014

[18] B. Ferdi, S. Dib, B. Berbaoui, and R. Dehini, "Design and simulation of dynamic voltage restorer based on fuzzy controller optimized by ANFIS," International Journal of Power Electronics and Drive Systems, vol. 4, no. 2, pp. 212–222, 2014, doi: 10.11591/ijpeds.v4i2.5685

[19] Smriti Dey, "Performance of DVR under various Fault conditions in Electrical Distribution System". IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE).2013

[20] S. Saravanan, M. Solaimanigandan, T. Tharaneetharan, V. Varunraj, and S. Parthasarathy, "Dynamic Voltage Restorer for Distribution System," vol. 7, no. 1, pp. 14–24, 2013

[21] C. K. Sundarabalan and K. Selvi, "Power quality enhancement in power distribution system using artificial intelligence based dynamic voltage restorer," International Journal on Electrical Engineering and Informatics, vol. 5, no. 4, pp. 433–446, Dec. 2013, doi: 10.15676/ijeei.2013.5.4.4.

[22] J Sivasankari, "Power Quality Improvement using Hysteresis Voltage Control of DVR," vol. 2, no. 1, pp. 1117–1124, 2014

[23] Saddam Subhi Salman, Abdulrahim Thiab Humod, Fadhil A. Hasan, "Dynamic voltage restorer based on particle swarm optimization algorithm and adaptive neuro-fuzzy inference system". ISSN: 2302-9285, DOI: 10.11591/eei.v11i6.4023…..2012

[24] J. Segundo-Ram´ırez, A. Medina, A. Ghosh, and G. Ledwich, "Stability boundary analysis of the dynamic voltage restorer in weak systems with dynamic loads," Int. J. Circuit Theory Appl., vol. 40, no. 6, pp. 551–569, Jun. 2012.

[25]] Noro, Y., Naoi, S., Toba, K., Kimura, M., Minegishi, T., Shimizu, M., ... & Okuda, Y. (2012, May). Power fluctuation suppression system for large scale PV. In PES T&D 2012 (pp. 1-6). IEEE

[26] J. Segundo-Ram´ırez, A. Medina, A. Ghosh, and G. Ledwich, "Stability boundary analysis of the dynamic voltage restorer in weak systems with dynamic loads," International Journal of Circuit Š eory and Applications, vol. 40, no. 6, pp. 551–569, Jun. 2012.

[27] González, P., Romero-Cadaval, E., González, E., & Guerrero, M. A. (2011, February). Impact of grid connected photovoltaic system in the power quality of a distribution network. In Doctoral Conference on Computing, Electrical and Industrial Systems (pp. 466- 473). Springer, Berlin, Heidelberg

[28] J. Tan, X. Lin, Y. Duan, and J. Qiu, "Optimized control for a DVR to compensate long duration voltage sag with low distortion at the load," 2011 International Conference on Electrical and Control Engineering, ICECE 2011-Proceedings, pp. 2414–2417, 2011, doi: 10.1109/ICECENG.2011.6057498.

[29] E. Babaei, M. F. Kangarlu, and M. Sabahi, "Mitigation of voltage disturbances using dynamic voltage testorer based on direct converters," IEEE Transactions on Power Delivery, vol. 25, no. 4, pp. 2676–2683, Oct. 2010, doi: 10.1109/TPWRD.2010.2054116

[30] "IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems," IEEE Standard 1547-2003, pp. 1–28, Jul. 2003