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Power Quality Improvement in Hybrid Sources Using DVR

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ABSTRACT
Hybrid renewable energy systems using solar and wind energy are becoming increasingly important due to growing energy demand, depletion of fossil fuels, and environmental concerns. However, renewable energy sources introduce several power quality issues such as voltage sag, voltage swell, harmonics, flickers, and interruptions because of their intermittent and variable nature. Among these problems, voltage sag is considered one of the most severe disturbances affecting sensitive electrical equipment. This review paper presents the role of Dynamic Voltage Restorer (DVR) in improving power quality in hybrid renewable energy systems. DVR is a custom power device connected in series with the distribution system to compensate voltage disturbances by injecting the required compensating voltage. The paper discusses the working principle, components, compensation techniques, and control strategies of DVR. Various control techniques such as PI Controller, Fuzzy Logic Controller, SRF Theory, and Adaptive Fuzzy PI Controller are reviewed. The benefits and applications of DVR in industrial systems, hospitals, data centers, and renewable energy systems are also discussed. DVR not only improves voltage stability and reduces harmonic distortion but also supports environmental sustainability by enhancing renewable energy utilization and reducing carbon emissions.

Index Terms
Dynamic Voltage Restorer (DVR), Hybrid Renewable Energy System, Power Quality, Voltage Sag, Harmonics, Solar Energy, Wind Energy, Renewable Energy, Main Grid and voltage swell.

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I.INTRODUCTION

Electrical power systems are rapidly shifting toward renewable energy sources because of increasing electricity demand and environmental concerns. Hybrid renewable energy systems combine multiple renewable sources such as solar and wind energy to provide reliable and continuous power supply. Although these systems offer clean and sustainable energy, they also create several power quality problems due to fluctuations in renewable energy generation.

Voltage sag, voltage swell, harmonics, flickers, interruptions, and unbalanced voltages are the most common disturbances observed in hybrid systems. These disturbances can affect the performance of sensitive electrical equipment such as computers, medical devices, industrial machines, and automation systems. Therefore, maintaining power quality has become an important challenge in modern electrical systems.

Dynamic Voltage Restorer (DVR) is one of the most effective custom power devices used for mitigating voltage-related disturbances. DVR injects the required compensating voltage into the distribution system and maintains stable load voltage during faults or disturbances.

II.LITERATURE REVIEW

1. "Dynamic Voltage Restorer (DVR) For Voltage Sag Mitigation" Mahmoud A. El-Gammal, Amr Y. Abou-Ghazala and Tarek I. El-Shennawy.

This paper presents a review of the Dynamic Voltage Restorer (DVR) is fast, flexible and efficient solution to voltage sag problem. The DVR is designed for protecting the whole plant with loads in the range of some MVA. The DVR can restore the load voltage within few milliseconds. Several configurations and control methods are proposed for the DVR. In this paper, an overview of the DVR, its functions, configurations, components, compensating strategies and control methods are reviewed along with the device capabilities and limitations.

2. "Mitigation Of Voltage Sags/Swells Using DVR" Rosli Omar and Nasrudinabd Rahim.
This paper presents a review of the researches on the DVR application for power quality Improvement in electrical distribution network. The types of DVR control strategies and its configuration has been discussed and may assist the researchers in this area to develop and proposed their new idea in order to build the prototype and controller

3. "Understanding Of Dynamic Voltage Restrorers Through Matlab Simulation" Paisan Boonchiam and Nadarajah Mithulananthan Thammasat.
This paper presents the application of dynamic voltage restorers (DVR) on power distribution Systems for mitigation of voltage sags/swells at critical loads. DVR is one of the compensating types of custom power devices. An adequate modeling and simulation of DVR, including controls in MATLAB, show the flexibility and easiness of the MATLAB environment in studying and understanding such compensating devices. The DVR, which is based on forced-commutated voltage source converter(VSC) has been proved suitable for the task of compensating voltage sags/swells.

4. "A Review Of Compensation Type Custom Power Devices For Power Quality Improvement" Yash Pal Swarup & Bhim Singh.
This paper deals with the deregulation of the electric power energy market, providing quality power has become an important concern of both power suppliers and customers . Efforts have been made to improve the power quality using passive filters, active power filters, hybrid filters and the new concept of custom power. This paper presents a comprehensive review of compensating custom power devices mainly DSTATCOM , DVR and UPQC.

5. "Generalized Proportional-Integral Control for Voltage-Sag Compensation in Dynamic Voltage Restorers" Alfonso Parreno Torres, Pedro Roncero-Sanchez, Xavier del Toro Garca and Vicente Feliu Batlle.
The Dynamic Voltage Restorer (DVR) is a custom power device used to protect sensitive loads in power distribution systems from the most frequent voltage disturbances, such as sags, swells, imbalances and harmonics. This paper presents a control strategy for voltage-sag compensation in DVR systems which offers an accurate tracking of the voltage compensation reference and a very fast transient response. The proposed control scheme is based on the technique known as Generalized Proportional-Integral (GPI) control.

6. "Feed Forward Control Strategy for the VSC of DVR for Smooth and Clean Power Flow to Load" Aamir Hanif, Mohammad Ahmed Choudhry And Tahir Mehmood.
VSC (Voltage Source Converter) feed-forward control strategy of DVR for an in-phase voltage injection scheme is proposed in this paper to tackle not only voltage sags and swells in the utility supply but also phase jumps as well. If the error in each phase of the utility voltage is greater than zero then appropriate control signals are generated. The switching devices in VSC are switched accordingly to compensate voltage sags, in the utility voltage that propagates to load.

7. "Study of Major Issues and Their Impact on DVR System Performance" Sunil Kumar Gupta, H.P. Tiwari, Ramesh Pachar.
This paper explains the issues and the impact of various factors on performance of Dynamic Voltage Restorer (DVR) system. A DVR is connected in power system for series voltage compensation. Voltage sags have significant affect on the performance of sensitive loads present in the distribution system.

8. "Voltage Sag Mitigation using DVR and DSTATCOM in Power System Network" Rasyidah Mohamad Idris & Rindiani Rosdi, Journal of Energy and Safety Technology.
This research combined DVR and DSTATCOM devices to reduce voltage sag problems in power system networks. The authors analyzed the coordinated operation of both devices under different fault conditions. Simulation results showed improved voltage stability and better compensation compared to using a single device. The paper concluded that hybrid compensation techniques enhance overall power quality.

9. "Voltage Sag Control in Hybrid Systems Using SMES-DVR" Koraboina et al., International Journal for Research in Applied Science & Engineering Technology.
The authors proposed a hybrid system using Superconducting Magnetic Energy Storage (SMES) with DVR for voltage sag control. SMES was used as an energy storage source to support DVR during disturbances. The study demonstrated improved compensation capability and faster recovery during faults. The paper proved that integrating energy storage with DVR increases system stability and performance.

10. "A Dynamic Voltage Restorer (DVR) for Protecting Hybrid Grids" Khodakhast Nasiriani & Mohsen Pasandi, Asian Basic and Applied Research Journal.
This paper explained the use of DVR for protecting hybrid renewable energy grids from voltage disturbances. The authors designed a DVR system suitable for grids containing solar and wind energy sources. Simulation results showed effective mitigation of voltage sag and improved power quality. The study highlighted DVR as a reliable solution for renewable energy integration.

11. "Power Quality Improvement by Using DVR" Ankita Pakale & Mukund Mahagaonkar, Journal of Electrical Engineering and Electronics Design.
In this paper, the authors studied the role of DVR in improving overall power quality. Different voltage disturbance conditions were analyzed using simulation models. The DVR successfully compensated voltage sag and maintained stable load voltage. The paper concluded that DVR is a cost-effective and efficient solution for sensitive industrial loads.

12. "Power Quality Improvement using Dual Voltage Source Converter Based DVR" A.Suresh & V.Govindaraj, IJETT.
This paper proposed a DVR system based on dual voltage source converters for better power quality enhancement. The authors developed an improved converter configuration to increase compensation capability and efficiency. Simulation results showed reduced harmonics and effective voltage regulation during disturbances. The paper demonstrated that advanced DVR structures can provide better performance in modern power systems.

III.CONCLUSION

The integration of solar and wind energy in hybrid power systems provides major environmental and economic advantages, but it also creates power quality problems such as voltage sag, swell, and harmonics due to the variable nature of renewable sources.

To overcome these issues, several compensation techniques such as series, shunt, passive, active, and hybrid compensation methods are used.Among these methods, the Dynamic Voltage Restorer (DVR) is considered one of the most effective solutions for voltage-related disturbances. DVR works as a series compensation device and quickly injects the required voltage into the system to maintain a stable load voltage during faults or disturbances. Advanced control techniques further improve its performance and response speed.

The use of DVR in hybrid renewable energy systems improves voltage stability, protects sensitive equipment, and enhances overall system reliability. MATLAB simulation studies also show that DVR effectively mitigates voltage sag and swell conditions.

The inclusion of the main grid in hybrid systems further increases reliability by supplying backup power during low renewable generation and enabling excess power transfer to the grid. However, this grid interaction can introduce additional disturbances. DVR helps maintain smooth power exchange and stable voltage conditions between the hybrid system and the grid.

In conclusion, DVR is a reliable, efficient, and cost-effective solution for improving power quality in modern hybrid renewable energy systems.

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