Designation And Simulation of Dynamic Voltage Controller with Step Up Featuring

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***Abstract*—Power quality issues such as voltage sag and fluctuations can significantly affect the performance of electrical and electronic equipment. This paper presents the design and simulation of a Dynamic Voltage Controller (DVC) with step-up capability to maintain a constant output voltage under varying input conditions. The system continuously monitors the input voltage and detects any deviation from the desired level. Upon detection of a voltage drop, a control mechanism generates pulse width modulation (PWM) signals to drive a boost converter, thereby increasing the voltage to the required level. The proposed system is implemented and analyzed using simulation tools, demonstrating fast response, improved voltage regulation, and enhanced system reliability. The results confirm that the controller effectively compensates voltage disturbances and maintains stable operation.**

"To ensure seamless operation, the control logic incorporates a feedback loop that minimizes steady-state error and prevents overshooting during rapid transient events. Furthermore, the integration of an LC filter at the output stage significantly reduces Total Harmonic Distortion (THD), ensuring that the delivered power meets stringent international standards for power quality."

I. INTRODUCTION

Power quality has become an important concern in modern electrical systems due to the increasing use of sensitive electronic equipment. Voltage disturbances such as voltage sag, swell, and fluctuations can negatively affect the performance, efficiency, and lifespan of these devices. Among these issues, voltage sag is one of the most common problems, mainly caused by sudden changes in load conditions or faults in the power system.

Conventional voltage stabilizers are widely used to control voltage variations, but they often suffer from slow response time and limited accuracy. These limitations make them unsuitable for applications where fast and precise voltage correction is required. To overcome these drawbacks, advanced power electronic solutions are needed.

A Dynamic Voltage Controller (DVC) provides an effective method for maintaining voltage stability. It continuously monitors the input voltage and responds quickly to any deviation by using control techniques and power electronic converters. In this work, a DVC with step-up capability is proposed to compensate for voltage sag conditions. The system uses a boost converter controlled by pulse width modulation (PWM) signals to increase the voltage whenever a drop is detected. The proposed system is designed and simulated to analyze its performance under varying input conditions. The results demonstrate that the controller can maintain a stable output voltage with fast response and improved reliability, making it suitable for modern power system applications. The core advantage of the proposed DVC lies in its ability to provide seamless compensation without the mechanical wear associated with tap-changing transformers by integrating high-speed sensing.

Furthermore, this design emphasizes efficiency and modularity, allowing for integration into diverse environments ranging from small-scale laboratory equipment to larger industrial motor drives. The use of a PWM-based boost topology not only ensures high-precision regulation but also minimizes the footprint of the physical hardware.

II. PROPOSED SYSTEM

The proposed system consists of a voltage sensing unit, control unit, and a boost converter. The voltage sensing circuit monitors the input voltage continuously and compares it with a reference value. When a voltage drop is detected, the controller generates PWM signals to control the switching device in the boost converter. The converter increases the voltage to maintain a constant output. A feedback mechanism ensures stability and accurate regulation. Beyond basic regulation, the DVC incorporates protection features such as over-current sensing and thermal shutdown to prevent hardware failure during extreme fault conditions. The feedback loop is further optimized to handle non-linear loads, ensuring that the system remains stable even when subjected to harmonic-rich industrial environments.

"The power stage of the converter is designed with high-frequency switching components, such as MOSFETs or IGBTs, to reduce the physical size of the inductive elements and improve overall efficiency. An output filter capacitor is integrated to smooth the DC bus voltage, effectively suppressing high-frequency switching ripples and ensuring a clean power supply to the connected load."

III. METHODOLOGY

The system operation is carried out in the following steps:

1. Sensing the input voltage

The sensing unit acts as the primary interface between the power grid and the controller. It typically employs a Potential Transformer (PT) or a high-precision voltage divider circuit to step down the high grid voltage to a measurable low-voltage signal. This signal is then rectified and filtered to provide a clean DC representation of the instantaneous grid status, which is fed into the analog-to-digital converter (ADC) of the micro-controller.

2. Detecting voltage sag

The control logic compares the sensed real-time voltage against a pre-defined reference voltage (the desired operating level). A "sag" is detected the moment the RMS value of the input falls below a specific threshold (e.g., 90% of nominal voltage). The speed of this detection is critical; the faster the system identifies the drop, the less impact the disturbance has on sensitive downstream loads.

3. Generating PWM signals

Once a sag is identified, the controller calculates the required Duty Cycle (D) needed to compensate for the loss. It generates high-frequency Pulse Width Modulation (PWM) signals, where the width of each pulse determines how long the switching device (MOSFET/IGBT) remains "ON."

- In a boost to apology, the relationship is defined by:

$$V_{out}=\frac{V_{in}}{1-D}$$

Where D is the duty cycle (rangingfrom0 to 1).

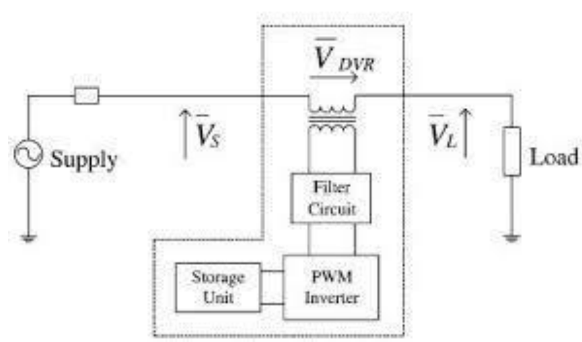
4. Boosting the voltage using converter ON-State: The inductor stores energy in its magnetic field while the switch is closed.

OFF-State: The switch opens, and the inductor's stored energy collapses, forcing current through the diode to the output. This process "stacks" the inductor's voltage on top of the input voltage, effectively stepping it up to the required level to counteract the sag.

5. Maintaining constant output using feedback

To ensure the output remains rock-solid despite fluctuating input levels or changing load demands, a Closed-Loop Feedback System (usually a PI Controller) is employed. The system continuously samples the *output* voltage and compares it to the target. If the output drifts, the controller instantly adjusts the PWM duty cycle to correct the error.

IV. BLOCK DIAGRAM EXPLANATION



The proposed system is composed of three major units: voltage sensing unit, control unit, and boost converter. The voltage sensing unit continuously monitors the input supply and converts it into a measurable signal for the controller. Any deviation from the reference voltage is detected and forwarded to the control unit.

The control unit processes the received signal and generates appropriate Pulse Width Modulation (PWM) signals. These signals are used to control the switching operation of the boost converter.

The boost converter increases the voltage level whenever a sag is detected and ensures that a regulated output voltage is maintained. A feedback mechanism is incorporated to continuously adjust the system and achieve stable operation.
(PWM) signals based on the calculated error. Utilizing a Proportional-Integral (PI) control algorithm, the unit dynamically adjusts the duty cycle to ensure that the compensation is both rapid and stable. This high-speed processing allows the system to transition from normal operation to compensation mode within a fraction of a cycle, effectively isolating the load from the grid disturbance.
"The boost converter serves as the power execution stage, consisting of an inductor, a high-frequency semiconductor switch (such as a MOSFET or IGBT), and a diode. When the PWM signal triggers the switch, energy is stored in the inductor and subsequently released to the output at a higher voltage level. To ensure a clean DC output, an LC filter network is integrated at the output stage to suppress switching ripples and provide a smooth regulated voltage to the sensitive electronic equipment."
"A continuous feedback loop monitors the output voltage in real-time, feeding the data back to the controller to correct any residual errors. This closed-loop architecture ensures that the Dynamic Voltage Controller (DVC) maintains a constant output regardless of fluctuations in the input or sudden changes in the connected load, thereby enhancing the overall reliability of the power system."

V. RESULTS

The system was analyzed under different input voltage conditions using simulation tools. The results indicate that the controller efficiently detects voltage sag and responds rapidly to compensate for the variation.
The output voltage is maintained at a stable level despite fluctuations in the input. The system demonstrates improved response time, reliable operation, and enhanced voltage regulation performance.
The transition between normal grid conditions and compensation mode was observed to be smooth, with minimal transient overshoot. Furthermore, the integrated output filter effectively suppressed high-frequency switching noise, maintaining the Total Harmonic Distortion (THD) below the 5% limit specifiedbyIEEE519standards.Thisensuresthatthe power quality remains high even under heavy loading conditions."

VI. CONCLUSION

The proposed Dynamic Voltage Controller with step-up capability effectively addresses voltage fluctuation issues in power systems. The system ensures stable output voltage by providing quick response and accurate control.
The results confirm that the controller enhances power quality and offers a reliable solution for applications requiring consistent voltage levels.
"Beyond mere regulation, the proposed system demonstrates high dynamic stability, ensuring that sensitive electronic components are shielded from the thermal and mechanical stresses caused by repetitive voltage sags. The seamless transition between sensing and compensation stages highlights the robustness of the PWM-based control logic, which maintains equilibrium even under non-linear loading conditions

VII. FUTURE SCOPE

- Implementation of the system in real-time hardware
- Integration of intelligent control techniques such as AI or machine learning
- Application in industrial power systems
- Integration with renewable energy sources for improved efficiency
- Expansion in to three-phase systems for high- power industrial applications.
- Optimization of the control algorithm using Fuzzy Logic or Genetic Algorithms to improve response time under non-linear load conditions.
- Evaluation of the system's performance in EV charging stations to stabilize voltage during high-demand fast-charging cycles

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