A Study on Droop and VOC Methods

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Abstract:- Grid-forming and grid-following inverters play crucial roles in modern power systems, each with distinct functionalities and advantages. This research paper aims to offer a thorough comparative analysis of these two inverter types, concentrating particularly on two grid-following methods: Droop and VOC. The paper explores the principles, merits, and demerits of each method and compares simulation results to assess their performance under overload conditions. The findings contribute to a deeper understanding of inverter technologies and inform decision-making in power system design and implementation.

Keywords:- *Grid-Forming Inverters, Grid-Following Inverters, Droop Method, VOC Method, Power System Stability.*

I. INTRODUCTION

Grid-forming inverters establish voltage and frequency in power systems, while grid-following inverters synchronize with the grid's voltage and frequency. Grid-forming inverters contribute stability and resilience, whereas grid-following inverters offer flexibility and compatibility. The aim is to compare two commonly used methods, Droop and Voc, in grid-following inverters by simulating them within the same power system and analyzing their performance. Both droop control, emulating the P/f and Q/V droop characteristics seen in traditional synchronous generators, and Voc control, ensuring grid voltage magnitude remains constant despite frequency fluctuations, are vital for maintaining grid stability and resilience. This research enhances understanding of optimal control strategies for grid-forming inverters in modern power systems by comparing simulation results.

II. LITERATURE REVIEW

Grid-forming and grid-following inverters are crucial components in modern power systems, each offering unique advantages and facing specific challenges. Among the various control methods used in grid-forming inverters, Droop control stands out as one of the most widely adopted techniques. Droop control, renowned for its simplicity and cost-effectiveness, replicates the P/f and Q/V droop characteristics observed in traditional synchronous generators. However, despite its widespread use, traditional Droop control has been associated with several limitations.

Discrepancies in line impedance among parallel converters can result in circulation effects, affecting the precise distribution of active and reactive power. Additionally, increasing the droop coefficient to improve load sharing accuracy often results in larger voltage regulation deviations. Moreover, harmonic circulation induced by the droop characteristics of the fundamental wave equivalent circuit can result in diminished power quality and sluggish dynamic response in the presence of nonlinear loads. To address these challenges, researchers have proposed various enhancements to traditional Droop control. For instance, in cases of strong line impedance, increasing the virtual impedance loop has been shown to improve system response characteristics. Nevertheless, this improvement may be accompanied by compromised voltage regulation performance and elevated open-circuit voltage. More recent studies have explored innovative approaches to improve the performance and reliability of Droop control in grid-forming inverters. Such approaches encompass integrating virtual impedance control with a virtual synchronous machine to mitigate converter output voltage deviation, along with adopting amplitude correction techniques to mitigate voltage fluctuations.

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Additionally, Virtual Oscillator Control (VOC) has emerged as a promising control technique for both grid-forming and grid-supporting inverters, providing time-domain synchronization with interconnected electrical networks. Existing studies underscore the significance of VOC in addressing grid voltage imbalance, a prevalent power quality event accounting for approximately 32.3% of all power quality events. By synthesizing these discoveries, this research seeks to contribute to the continuous endeavors aimed at optimizing the performance of grid-forming inverters and bolstering the stability and resilience of contemporary power systems.

III. METHODOLOGY

The methodology employed in this study aimed to assess the performance of a simulated power system comprising two grid-forming converters (GFCs) and one synchronous generator (SG), adhering to standard grid specifications of 230 V voltage and 50 Hz frequency. The simulation, conducted using MATLAB/Simulink, spanned a duration equivalent to 2 complete cycles of the grid frequency, representing a time span of 40 ms.

The simulation setup incorporated the introduction of a fault scenario at 25 seconds into the simulation, mimicking abnormal operating conditions. Additionally, an extra load of 75 MW was introduced at the same time to evaluate the system's response to increased demand. The objective was to observe and analyze the behavior of the system components, including GFCs and SG, under dynamic operating conditions in the paper.

IV. SIMULATION RESULTS

The analysis of simulations conducted on both Droop Control and Virtual Oscillator Control (VOC) revealed notable characteristics in the behavior of frequency, voltage, and power parameters.

➢ *Droop Control:*

Under Droop Control, the system exhibited a significant droop in frequency compared to voltage and power. This behavior is consistent with the inherent droop characteristics of traditional synchronous generators, where frequency decreases as power demand increases. Despite maintaining voltage within acceptable limits, the frequency showed a pronounced deviation from the nominal value, indicating a strong coupling between frequency and power output in the system. The observed droop in frequency highlights the effectiveness of Droop Control in regulating power flow and maintaining grid stability, albeit at the expense of frequency deviation.

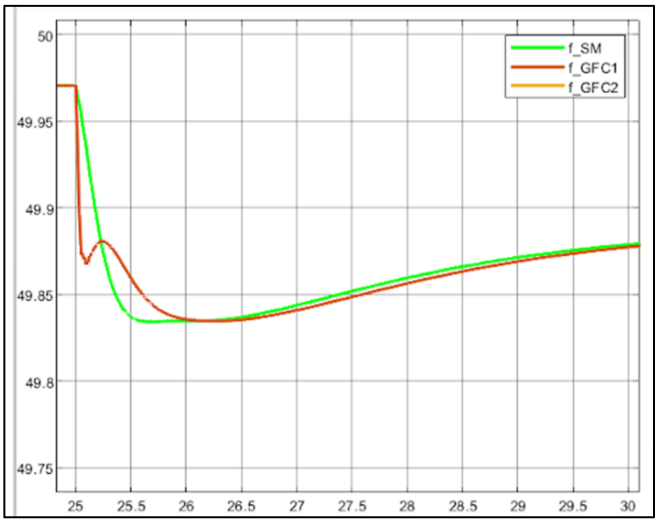

Fig 1: Frequency Response of Droop Control

➢ *Virtual Oscillator Control (VOC):*

Similarly, simulations conducted with VOC demonstrated a significant droop in frequency relative to voltage and power parameters. However, the droop characteristics observed under VOC differed from those observed under Droop Control. VOC exhibited a more dynamic response to changes in power demand, with frequency exhibiting rapid fluctuations in response to load variations. This behavior can be attributed to the time-domain synchronization provided by VOC, which enables faster response times compared to traditional droop control methods. Despite the dynamic nature of frequency fluctuations, voltage and power remained relatively stable within the specified limits, indicating the robustness of VOC in maintaining grid stability under varying operating conditions. Overall, the simulation analysis revealed that both Droop Control and VOC exhibit significant droop in frequency compared to voltage and power parameters. While Droop Control demonstrates a more gradual response to changes in power demand, VOC offers a more dynamic and responsive approach to frequency regulation. These findings provide valuable insights into the performance of grid-forming control strategies and their impact on grid stability and reliability.

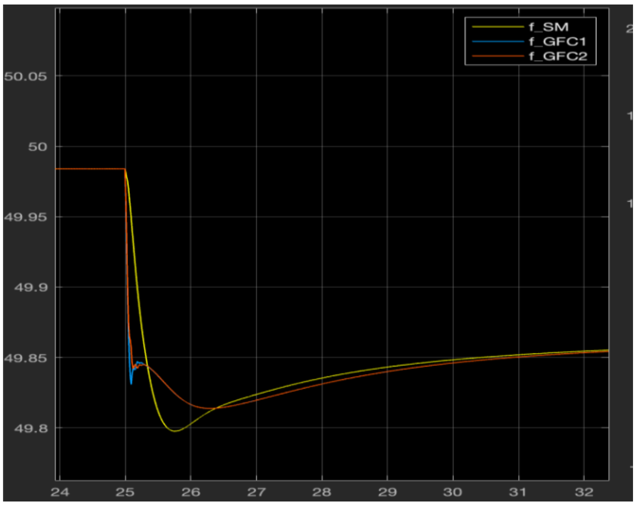

Fig 2: Frequency Response of VOC

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V. CONCLUSION

Both Droop Control and Virtual Oscillator Control (VOC) exhibit significant frequency droop compared to voltage and power parameters, highlighting their effectiveness in regulating power flow and maintaining grid stability. An application where Droop Control excels is in traditional power systems with synchronous generators. Its gradual response to changes in power demand aligns well with the characteristics of synchronous generators, making it suitable for grid-forming applications where stability is paramount. On the other hand, VOC offers a more dynamic and responsive approach to frequency regulation, making it well- suited for microgrid and renewable energy systems. Its time-domain synchronization capabilities enable faster response times, making it ideal for grid-forming inverters in distributed energy systems with fluctuating loads and intermittent renewable energy sources. When deciding between Droop Control and VOC, the choice depends on the specific requirements of the application. Droop Control is preferred for traditional power systems where stability is critical and gradual frequency response is acceptable. In contrast, VOC is preferred for microgrid and renewable energy systems where rapid response to changing conditions is essential for maintaining grid stability and reliability.

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