# Evaluation of Frequency Support using Synthetic Inertia for GFM Inverters

**Shanmugapreethi V[a] and Dr. D Prasad[b]**

[a] Sona College of Technology, Salem, India
[b]Sona College of Technology, Salem, India

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**Abstract:** Grid-following(GFL) PV inverter cannot control the voltage and frequency of the grid. With the high penetration of renewable resources into the grid, the inertia of the system was reduced drastically. This leads to frequency stability problems especially when there is excessive power generated. This study represents the ability to increase the frequency using virtual inertia. Implementation of virtual inertia could damp out all the frequency oscillations and improves the grid stability. The inverters which can control the voltage and the frequency of the grid are known as the grid-forming(GFM) inverters. GFM inverters help in damping the frequency oscillations while the GFM inverters increase the problems related to frequency stability. To exploit the innate damping of GFM inverters energy reserves are critical. Implementation of the virtual inertial in renewable machine controls could increase the power quality. The network has been simulated in PSS®E from which the respective dynamic studies results have been obtained.

**Keywords:** VI- Virtual inertia, grid-forming inverter, grid-following inverters; frequency stability; droop control; damping; low inertia system

## 1. Introduction

With a high penetration of Renewable resources into the grid, the grid support functionality which is traditionally provided by the rotating machine with high mass is decreased. It is expected that the renewable machine should provide voltage and frequency support in the replacement of rotating machines. The stored kinetic energy in the rotating machine could provide frequency stability. The PV inertia does not have any kind of stored kinetic energy to improve the stability. With an increase in the penetration of renewable resources, the inertia of the system is reduced, and the stability of the grid becomes the main concern. With the implementation of virtual inertia, the rate of change of the frequency can be slow down.

As the solar plants and wind generators typically have no inertia, they operated in the rated capacity and do not provide any active power support during a change in the frequency. The total inertia of the grid is becoming with an increase in renewable resources and the electro-mechanical energy of the system is decreased. As the kinetic energy storage is decommissioned, larger frequency swings can be encountered. With these large frequency swings, a high level of reliability issues is caused by miscellaneous tripping.

GFL inverters do not provide any kind of voltage or frequency support and they are simply represented as a negative load in the modeling studies. The next generation of inverters that could control the voltage and frequency of the grid is called the grid following inverters. These grid-forming inverters can provide grid support using the current control philosophy. Grid-forming control allows for direct control of voltage and frequency. If renewable machines could provide frequency support like a rotating machine, all kinds of stability issues can be resolved. To achieve frequency stability, the implementation of synthetic inertia in grid-forming inverters is proposed. Virtual inertia concept was completed evolved from swing equation. Virtual inertia can be conceptualized only if there is extra power available.

Traditional PV inverters frequency support was using a droop control and the proposed VI concept could be an addition to the droop control output. From the simulation results, we can conclude that by implementing VI we can achieve frequency support by obtaining stability through faster response.

## 2. Implementation of virtual inertia

Frequency regulation or the response can be categorized into three stages. The first stage could be the primary response which is also stated as the inertial response. The second stage is called a secondary response which could be from the governor controller or the AGC. The third stage is called the tertiary response which could from all the reserve frequency restoration functions.

Emulated inertia will take part in the primary stage to improve the inertial response of the system by damping the frequency through faster frequency response.

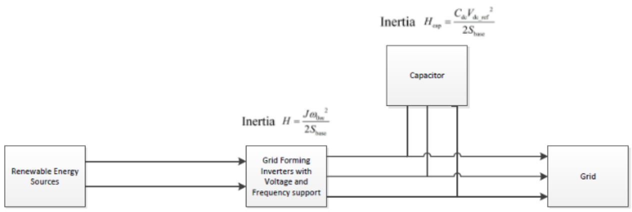


Figure 1: Grid Forming Inverter simplified blocked diagram

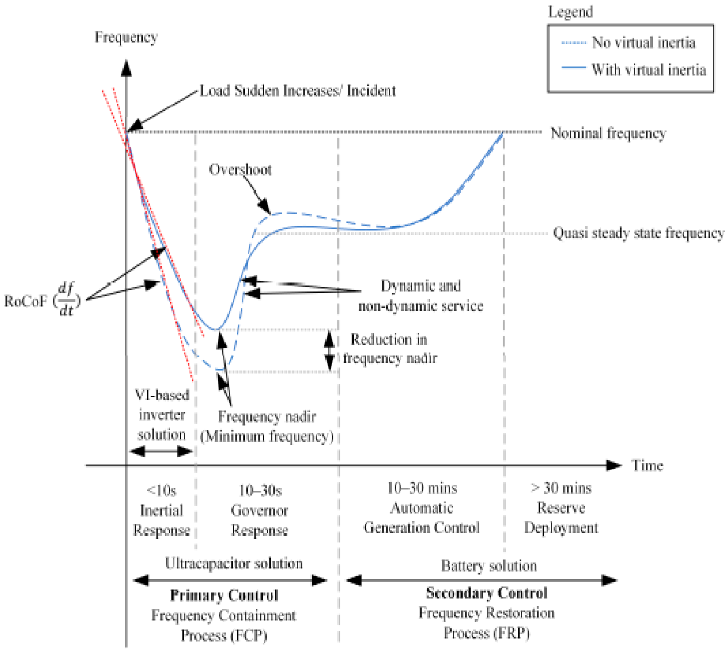


Figure 2: The effect of Virtual Inertia in low inertia system

Grid-forming inverters are intrinsically different from GFL inverters. GFM inverters are current-controlled voltage sources that can act as a conventional rotating machine with a coupling reactance. Voltage source inverters with droop characteristics allow for direct control of voltage and frequency. The droop control logic in the GFM inverter could increase or decrease the output power to maintain the voltage and frequency of the grid. The response of the droop controller in the GFM is very fast. Therefore, GFM sources respond much faster to any contingencies than the response of the GFL sources. Providing primary frequency control from inverter-based resources could be very advantageous particularly for "low-inertia" power systems. Compared to large synchronous machines, inverter-based resources can change their output much faster thus arresting the system's frequency changes before any load shedding is triggered. The slow frequency dynamic response is predominantly affected by the mechanical inertia and turbine-governor dynamics of generators.

Swing Equation-based active power control of the PV inverters provides faster response frequency restoration and it helps to increase the inertia of the system by injecting extra available power into the grid for any frequency contingency.

## 3. Generator/ inverter dynamics

Solar plants consist large number of inverters which increases the complexity of modeling the controls. GFM inverter has the nature of injecting high current instantaneous even for a small disturbance. This is mainly due to the absence of inertia in the system. These complexities can be reduced by introducing emulated inertia which can help GFM inverter to act as an autonomous source.

Most of the inverters act very fast for a small change in load with the help of frequency droop controls. This could lead to miscellaneous trips and the system loses its stability.

With a high level of renewable sources, we expect the inverters to reach their power limit at a much faster rate compared to others. If there are any contingency events due to the trip of large generators, power shortage will be restored by increasing the output of other generators. However, leveraging traditional generation assets for creating reserved capacity creates several inefficiencies. The GFM with virtual inertia control will be able to restore the frequency by the faster response.

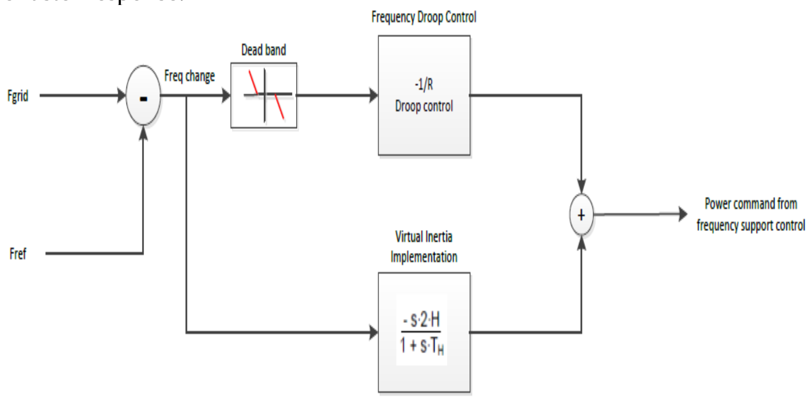


Figure 3: Inverter dynamic with Virtual Inertia

The reserve power value is

$$\Delta P = P\text{mpp} - P\text{v,o}$$

where $\Delta P$ reserved power and Ppvo is the value of output power from the PV source. It is implemented by adjusting the power setpoint of the PV source to insure needed reserved power. Two possible operating points can be obtained because of the non-monotonic characters of the inverters.. The operating point with voltage less than MPP can introduce over-modulation issues and instability for grid forming PV sources. It is necessary to ensure the availability of excess power for the operation. To implement the power reserve concept on grid-forming PV sources, tracking the time-variant maximum available power is a key requirement.

Thus, the feedbacks of the virtual frequency differential item are introduced to change the operating point of the PV generator, as follows:

$$\Delta \text{Pcmnd} = \text{-S2H/1+STSH}$$

Which is derived from the swing equation.

Virtual inertia can inject higher power which could minimize the frequency nadris and peaks during any contingency event.

**4. Simulations**

A user-written model for Inverters was developed with a frequency control logic. A sample system is considered with multiple synchronous generations and a PV model with VI Implementation. The response of the system was evaluated without PV and with PV after the implementation of the VI concept.

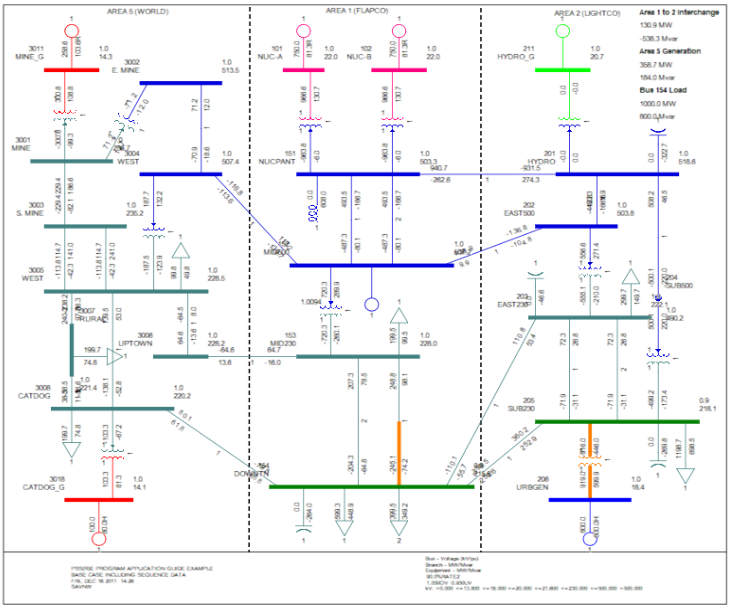

Figure 4: Sample test system

**5. Results**

The results of the systems' response to a sudden loss of generation with different operation scenarios are shown in Figure 5. The overlap curves illustrate that the inertial contributions from the PV-side generation have a faster frequency damping.

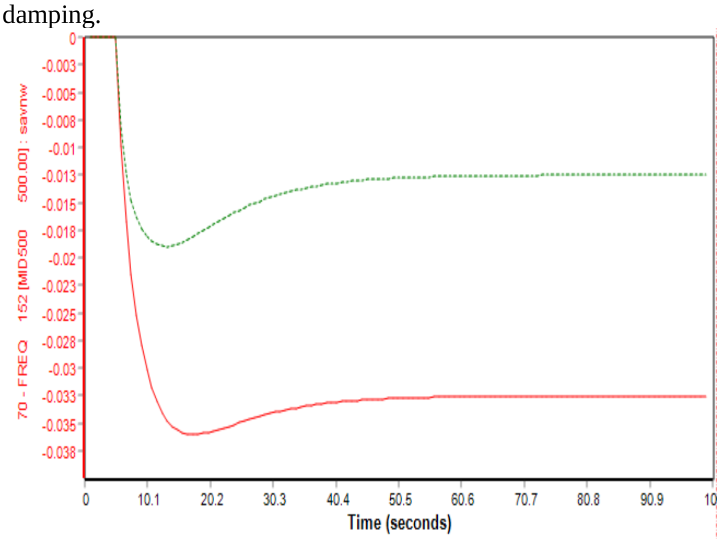


Figure 5: Simulation Result

**6. Conclusions**

From the simulation results, it can be concluded that the implementation of virtual inertia improves the frequency response of the system and helps to attain frequency stability. Synthetic inertia could be a viable solution to attain frequency stability in a low inertia system The proposed model has been validated and opened up a wide of research to improve grid stability.

**References**

1. Kah Yung Yap, Charles R. Sarimuthu, and Joanne Mun-Yee Lim, "Virtual Inertia-Based Inverters for Mitigating Frequency Instability in Grid-Connected Renewable Energy System: A Review," 47500 Subang Jaya, Selangor Darul Ehsan, Malaysia, September 2019. *(references)*
2. Xin Huang, KeyouWang, Guojie Li and Hua Zhang, "Virtual Inertia-Based Control Strategy of Two-Stage Photovoltaic Inverters for Frequency Support in Islanded Micro-Grid," 4 Sichuan Electrical Power Research Institute, Chengdu 610000, July 2018. (references)