

Virtual Inertia Emulation in a Hybrid Micro Grid Based on Diesel Generator and Wind Power Plant

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Abstract— Micro-grids with high renewable penetration have low inertia and it leads to frequency stability problems. Virtual inertia emulation provides active power to system during transient time to improve dynamics frequency stability. In this study, derivative technique is used to calculate the derivative of frequency for virtual inertia emulation. Simulations results confirm that frequency dip occurs in case of contingency and virtual inertia control reduces this frequency deviation. It helps to improve overall frequency stability and prevents unnecessary load shedding.

Keywords— Power System Stability, Micro-grids, Renewable Energy Sources, Frequency Control, Virtual Inertia.

I. INTRODUCTION

Environmental concerns, energy policies and giving access to electricity in remote areas have encouraged distributed generation and increasing penetration of RES in power system [1]. Distributed generation introduced a new concept of a small-scale power system known as micro grid. A micro grid is a group of power grids with RES sources and loads, and it can be identified as an independent system [2]. The concept of micro grid has played a vital role in the development of electricity market. However, it reduced the inertia of the system due small size, inverter/converter based technology of RES, and led to frequency stability issues [3]. Power system based on synchronous generators follows the frequency regulations. Inertial response, primary frequency control and automatic generation control attenuate the system dynamics and decrease frequency deviation of the system, so that system instability, cascaded outages and blackout can be avoided [4]. Thus, the main concern about the safe operation and control of today's and future micro-grid is its dynamic stability as system inertia is decreasing due to increasing penetration of RES.

A novel technique known as virtual inertia emulation address these stability issues. Virtual inertia is a combination of control algorithm, power electronics circuits, energy sources and energy storage systems, which emulates the inertial behavior of synchronous generator in RES, based micro-grid

[5]. Several studies of virtual inertia emulation have discussed in the literature. Bryant et al [6] described the challenges of frequency control in Australian's power system due to increasing share of renewable power generation. Obaid et al [7] described challenges and new methods to control frequency of future power system. The virtual inertia injection in multiple PV systems of autonomous micro grid is discussed in [8]. Unlike synchronous and wind turbine, solar photovoltaic system does not possess any type of kinetic energy and it does not injects any inertial property in power system. DC link capacitor's voltage is adjusted to add virtual inertia and it injects or absorbs power when frequency changes occur. Kerdphol et al [9] proposes a new technique, which simultaneously injects the virtual inertia and virtual damping in a micro grid using derivative frequency approach. A virtual inertia control technique, VISMA or VSG is applied to imitate the virtual inertia and virtual damping in RE generating sources, which is the dynamic behavior of synchronous generator. In [10], frequency dynamics of hydropower system are modeled which helps to injection of virtual inertia. In [11], all techniques which are used virtual inertia emulation in micro grid are discussed and compared. Novel approaches are applied and proposed to inject inertial response in both voltage source and current source inverter. Bevrani et al [12] describes application of virtual inertia in frequency control of power grid. In this paper, the dynamics of the frequency deviations caused by parallel operation of the grid and VSG are analyzed, and the stabilization effects provided by VSGs are confirmed. In [13], optimization of emulated inertia is discussed. It is important to explore that where to place this inertia optimally as it is considered that placement of inertia has significant impact on power system performance. Some global as well as local optimal solution of virtual inertia problems are presented in [13].

This paper presents the $\frac{df}{dt}$ technique of virtual inertia emulation. Virtual inertia power is calculated based on ROCOF of the system. VI loop helps to maintain the frequency stability of the micro-grid based on conventional and RES generating units during transient time. The reminder part of this paper is arranged as; Section II explains the modeling of micro-grid,

occurrence of contingency and design of virtual inertia loop. Section IV shows the behavior of frequency with and without virtual inertia emulation. Finally, conclusion are presented in section V.

II. METHODOLOGY

The methodology include simulations of micro grid in MATLAB/SIMULINK, injection of a perturbation on micro grid and its analysis, emulation of virtual inertia loop on perturbed system and its analysis.

A. Modeling of Micro Grid

To access the system having shares of conventional power sources and RES, a model of micro-grid based on diesel generator and wind power plant is designed on MATLAB/Simulink. The connection of grid side inverter of wind turbine with diesel through transformer and filter L is similar with simple integration of inverter with grid. The voltage and current are measured at the point of common coupling, which are transformed from a,b,c sequence to d,q,0 sequence. PLL is used to measure frequency and phase angle.

The measured value of three-phase voltage and current are sent into the power calculations block to measure the instantaneous value of active and reactive power. These measured values are compared with the P_{ref} and Q_{ref} and sent it to PI controller. PI calculates error between measured value and desired values and tries to minimize it. The control of active and reactive power is called outer control loop and its purpose to generate a reference dq sequence ($I_{d,ref}$ and $I_{q,ref}$) current. These reference dq currents are sent to the inner loop that is called current control loop where measured dq currents are compared with these reference currents and error is minimized by PI controller. The reference output voltage must

be equal to the voltage and frequency at PCC. This reference voltage is sent to the PWM generator that generates the trigger signal for voltage side inverter.

B. Occurance of Perturbation

The rating parameters of the system are shown in table. An initial load of 400 KW is connected with the system, at $t = 10 \text{ sec}$, a step load of 100 KW is added and behavior of the frequency is observed during transient time.

TABLE I. PARAMETERS OF THE SYSTEM

Sr. No.	Parameter	Rating
1	diesel generator	300 KW
2	wind power plant	200 KW
3	transformer rating	500KVA
4	frequency	50 Hz
5	V_{abc}	380

C. Virtual Inertia Loop

In order to meet the contingency of load and generation imbalance, an algorithm is developed based on energy storage system, inverters and control loops called virtual inertia. It plays the role of kinetic energy released in synchronous generator when load-generation miss-match occurs and works as a function of frequency decay and ROCOF. It activates only when frequency deviations occur and becomes inactive when frequency goes back to nominal position (50Hz). Wind power plant inverter is operated below its maximum power and some

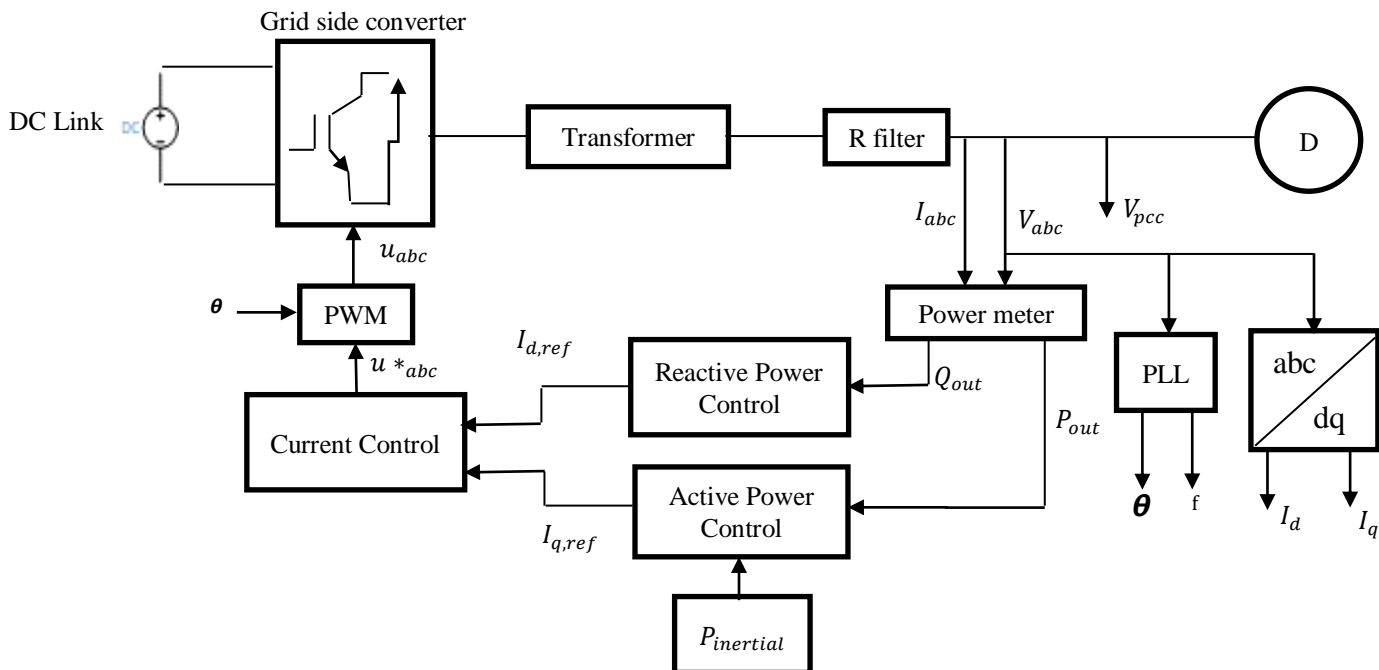


Figure.1 Modeling and control of micro-grid

power is kept in reserves. Virtual inertia loop is coupled with this reserve power and it activates during transient state when ROCOF occurs. Inverter supplies reserve power to load in proportion to ROCOF and it is calculated as follows:

$$P_{vs_g} = K_I \frac{d\Delta\omega}{dt} \tag{1}$$

Where P_{vs_g} is virtual inertia power, K_I is inertial constant and $\Delta\omega$ is frequency deviation. The designed virtual inertia loop is shown in figure (2).

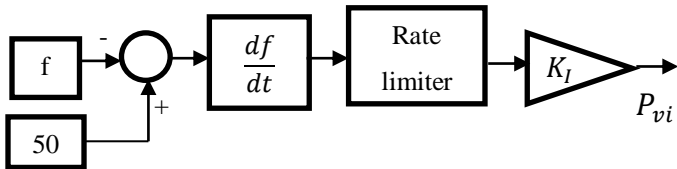


Figure 2. Virtual inertia loop.

III. RESULTS

The research work consists of one conventional power plant (synchronous generator) and one RES power plant (wind power plant). The results are discussed the active power flow and frequency deviations with and without virtual inertia emulation.

A. Active Power Flow

The power generation of wind power plant is shown in figure (3), which is constant 200KW. The power drawn by the load is called the active power of the system. Initially, it is 400KW and after that 100KW load is added at $t=10\text{sec.}$, figure (4) shows the active power of the system.

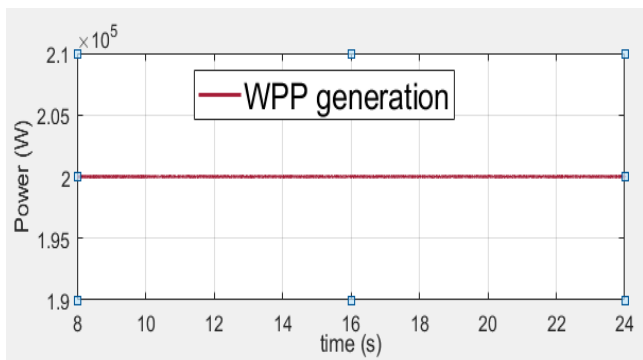


Figure 3. Wind Power Generation

It is cleared from the figure (3) that wind power plant supplies 200KW power to load and figure(4) shows that load power varies from 400KW – 500KW. The extra power comes from diesel generator. It supplies 200KW power initially and 100KW extra power when step load is applied. Figure (5) shows the power production of diesel generator.

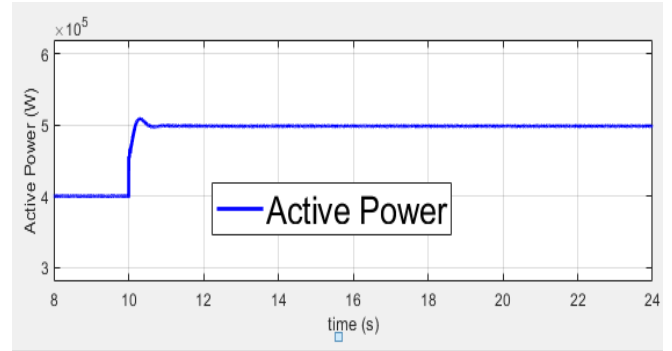


Figure 4. Active Power.

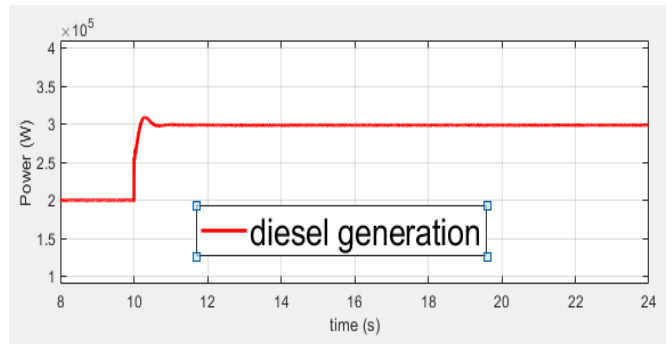


Figure 5. Diesel generation

B. Frequency Behavior

A frequency dip occurs at $t = 10\text{sec}$ when step load is applied without virtual inertia emulation. Figure (6) shows that frequency deviated from 50 Hz to 49.28 Hz. Activation of virtual inertial loop provides active power during transient time, catches the ROCOF, and improves the frequency nadir. Figure (7) shows the comparison of frequency with and without the application of virtual inertia loop. It is seen that virtual inertia emulation improves the frequency from 49.28Hz to 49.4 Hz. It increases the stability, resiliency and reliability of power system with high penetration of RES and encourages the installation of micro grids.

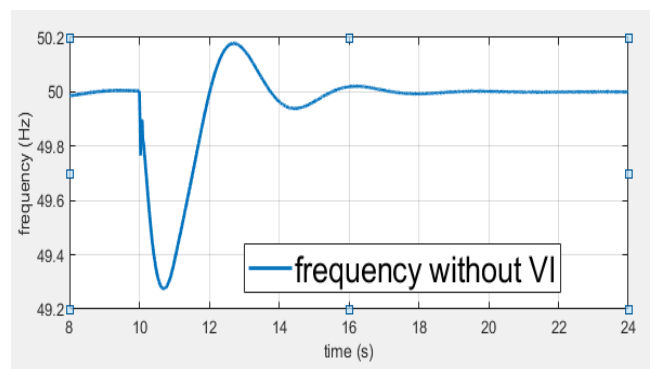


Figure 6. Frequency behavior without virtual inertia

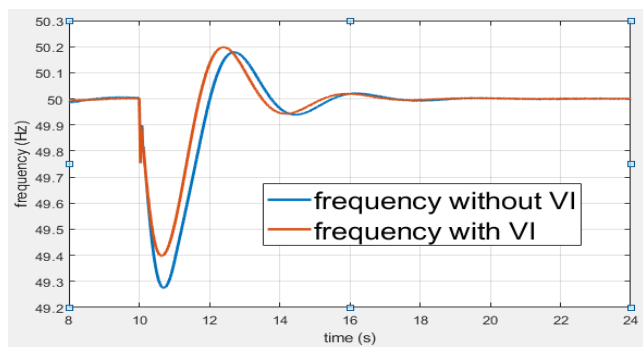


Figure 7. Frequency comparison with and without virtual inertia.

CONCLUSION

Power system is shifting from large conventional power plants to small DG and RES based generating units. They have small size and possess power electronics technologies. Hence, they have low inertia and consequently today's power system is facing frequency stability issues. Virtual inertia emulation is a technique used to improve frequency stability while supplying active power to system during transient time as a replica of kinetic energy in synchronous generator. In this research study, a methodology of virtual inertia emulation is applied on a micro grid having shares of conventional as well as RES. Simulation results confirm that when a contingency is applied in form of step load at $t = 10\text{sec}$, frequency dip occurs during transient time and it may lead to shutdown of some portion of the system. Proposed virtual inertia emulation technique improves this frequency decay, increases the transient frequency stability and ensures the safe operation of the system.

Future work on this area of study can be done by considering virtual damping emulation along with virtual inertia. Consideration of virtual damping can give better performance. Optimal placement of virtual inertia and virtual damping can also be added. Cost analysis and optimization of virtual inertia for designed system needs to be done. A hardware prototype of virtual inertia can be developed and verified.

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