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# Coordinated active power control of Wind, Solar and Diesel Generator in a Microgrid

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**Abstract:** In this paper, a microgrid consisting of a fixed speed diesel generator and renewable energy sources (Photo Voltaic and PMSG based variable speed Wind Energy Conversion Systems) have been considered. The photo voltaic source is operated in a derating mode and the wind generator in inertia control mode in order to mitigate the active power imbalance in the microgrid. An advanced photo voltaic derating algorithm is introduced based on the rate of change of PV power with respect to the voltage. This coordinated control limits the ramp rate of the diesel generator and operates it in the economical operating zone. The control scheme is tested for change in solar irradiation and load demand.



*Keywords:* Diesel generator, Derating, Inertia control, Microgrid, Photo Voltaic, Wind Energy Conversion Systems.

## 1. INTRODUCTION

With the increase in the percentage of penetration of wind and solar generation in the micro grids, there has been a growing concern about the low inertia and the mitigation of active power imbalances in the system. One can handle this situation by placing fossil fuel generators with high ramp rate so as to have a better frequency response. But generating power with high ramp rates will come at a cost of the reduced life of the generators. For instance, K. R. Hoopingarner et al. (1989) describes that a quick start of a diesel generator (DG) can reduce its life. So instead we can use the wind turbine inertia and the reserve power of the derated photo voltaic (PV) source in order to provide primary frequency response.

Z.-S Zhang et al. (2012) discuss the problems of high wind penetration. Due to the wind uncertainties, the high wind power penetration has resulted in the curtailment of wind power due to the problem of frequency instability. In order to avoid such problems and to improve frequency regulation, it is a high priority to use the wind turbine inertia for the frequency control. Moreover, as the wind turbines can have inertia values up to six times that of its generator, as given by G. Ramtharan et al. (2007), it is highly advantageous to use kinetic energy of the wind turbine for frequency regulation. In this paper, an inertia control technique in a PMSG type variable speed wind generator has been introduced to reduce the active power imbalances in the microgrid due to varying wind speeds, load and insolation. In the proposed control, an auxiliary control that pertains to the change of microgrid frequency is being used in addition to the conventional power point tracking controller for generating the power order for the wind generator.

In the literature there has been frequent use of wind turbine inertia for the frequency control. The use of proportional differential controller has been presented by Zhiheng Zhang et al. (2013) for a DFIG based wind conversion system. There has also been schemes where the Optimal Power Point Tracking (OPPT) of the turbine has been manipulated for the frequency regulation, described by Zhiheng Zhang et al. (2013). Moreover, high $K_p$ and $K_d$ values of a PD controller will bring in a significant contribution of wind turbine in frequency control but will bring in a significant wear and tear in the mechanical components, especially in the gear box (in case of a DFIG based wind generator). Though the optimal values of $K_p$ and $K_d$ have been calculated based on wind turbine stability by Z.-S Zhang et al. (2012), but it is done without taking into consideration the mechanical stresses that will be induced and will reduce the life of the mechanical couplings.

In this paper by using a proportional controller the demand for frequency support from the wind is restrained and the solar power is used instead to provide additional frequency regulation, so that the combined contribution of the solar and the wind power in the frequency support will bring better frequency regulation even in systems with high renewable energy penetration.

In the PV array a derating algorithm has been employed that is based on the rate of change of power with respect to the voltage. The derating is based on the values stored in a lookup table of the rate of change of power with respect to the voltage, corresponding to desired reserve, which is computed based on the power output. Hence through this mechanism a constant percentage derating can be obtained irrespective of the solar irradiation.

To validate the proposed control scheme, a microgrid with high penetration of wind and solar power is considered as a test system.


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## 2. MICROGRID DETAILS

The system considered in this paper comprises of a fixed speed DG, PMSG based variable speed wind generator and PV array having ratings of 2 MVA, 1MW and 1.1 MW respectively. The complete system under study is shown in Fig. 1.

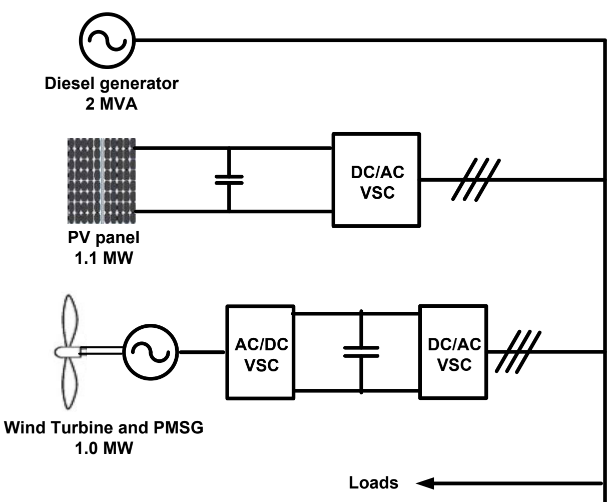


Fig. 1. Microgrid consisting of DG, PV array and wind turbine.

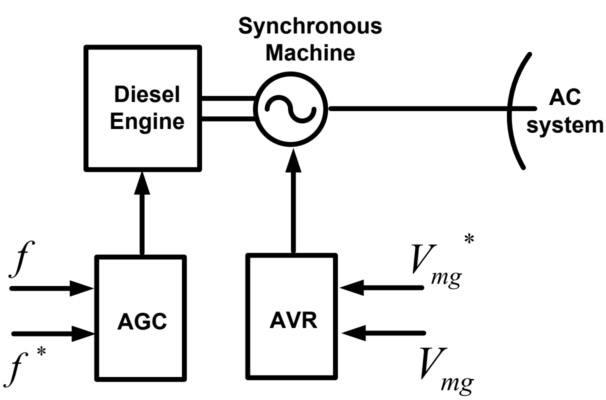


Fig. 2. Control of DG.

The DG control is done by using conventional automatic generation control for frequency regulation and automatic voltage regulator for its terminal voltage regulation; as shown in Fig. 2. The wind generator is controlled using its inertia while the PV array is operated in derating mode.

The secondary frequency control lies with the DG while the renewable energy sources help in the primary frequency regulation; thus helping in reducing the ramping of DG.

## 3. PMSG CONTROL

PMSG based wind energy conversion system is used in this paper for being more popular these days. Moreover, their LVRT capabilities, gearless transmission and better controllability as compared to DFIG based systems gives them an upper hand when compared with DFIG based wind energy conversion systems.

In the Maximum power tracking of the wind generator the power command is set based on the rotor speed. This power control is translated into torque command and subsequently to current command. So whenever there is an increase in the wind speed, the rotor speed increases and hence the power command. But if by some means we increase the power command on a fixed wind speed scenario, then in order to obey the power command, the extra amount of power is drawn from the rotor inertia. This results in the overall reduction in the rotor speed. Hence, by adding an auxiliary signal that pertains to the change in frequency, in the power command obtained by the MPPT algorithm, we can manipulate the power output of the wind generator. This will also result in better frequency regulation of the microgrid by regulating the power output at the wind generator terminals based on the frequency of the microgrid.

The power output at the terminals of a generator could be written as:

$$P_{ele} = P_{input} - J\frac{d\omega}{dt} \quad (1)$$

The term $J\frac{d\omega}{dt}$ constitutes the inertial power that is either consumed in or dissipated from the generator, when the generator accelerates or decelerates respectively. In a wind generator, unlike a conventional synchronous generator we can control the rotor speed or the inertial power irrespective of the grid frequency. Now the key to the participation of wind generators in the frequency response lies in using this inertial power. The control scheme using the inertial power is shown in Fig. 3.

## 4. PV CONTROL

A PV source operating in derating mode can be treated as a reserve power which can be used for better frequency regulation as shown by P.P. Zarina et al. (2014). Maximum Power Point Tracking (MPPT) Algorithm provides the reference voltage to operate the PV at its maximum power. Various MPPT algorithms are available in literature; most of these discussed by Trishan Esram et al. (2007). To keep a reserve power the PV is operated in derating mode and such operation is achieved by modulating the reference voltage to operate the system at the voltage greater than the MPP voltage. However, the change in reference voltage needs to be decided as per the reserve required.