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Improving the Frequency response of a Microgrid using an Auxiliary Signal in the AGC Loop

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***Abstract*—This paper improves the frequency response of a microgrid by including an additional signal in the AGC loop. The system frequency is an indication of the power balance between the generation and the load, moment to moment. The generators employ Automatic Generation Control (AGC) to regulate the power generated to keep the frequency as required. Considering the standard IEEE 15, 33 and 69 bus distribution systems as Microgrid, the proposed control logic is tested for its performance against the existing governor control. The additional signal chosen is the power mismatch after the load change and it is used to modify the generator mechanical input given by the existing governor control. The proposed method is compared against the existing governor control. In this paper, the power source considered is bio-diesel powered synchronous generators. In the upcoming de-regulated energy environment, if the generators acts as frequency response reserves-the system performance as well as the monetary benefits for the generators will improve.**

***Keywords*—Distributed generation, Frequency control, Micro-grids, Bio-diesel.**

I. INTRODUCTION

A microgrid is a locally grouped electric generation, storage and loads that normally operates connected to a power system. The microgrid is also capable of functioning autonomously. The loads and generations are interconnected at low voltage levels. The microgrid is controllable and so from the point of the grid operator, it can be viewed as if it were a single entity. As per Smart Grid, An Introduction (2008) microgrids are essentially modern, small-scale (electrical) power distribution systems. They afford numerous benefits, such as enhancing system reliability, reducing capital investment and carbon footprint.

The generators used for microgrids are called Dispersed or Distributed generators (DG) or Distributed Energy Resources (DER). Due to this decentralized approach of electric generation, microgrids are comparatively efficient, reliable and secure than the conventional grid. Microgrids are capable of autonomous operation, during main grid black-outs or brown-outs .

As generation is at load site, it reduces the transmission and distribution losses as well as cost. In a deregulated environment, this can also be considered for by-passing congestion.

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The generation in microgrid is usually from different sources like Solar-Photovoltaic, Wind Turbines, Diesel Generators, Fuel Cells, Combined Heat and Power and Bio-mass powered sources.
An electric grid is dynamic (i.e., the operating conditions are always changing). Whenever the loads changes, the total generation needs to be adjusted to achieve power balance and to operate at the designed frequency. The microgrid can be having different types of DG's which may or may not have inertia.

When there is a sudden change in load the available rotational inertia gives the balancing energy and tries to keep the frequency at the nominal operating point. Baggini (2008) describes the initial response of the rotating machine to the change in frequency as primary frequency response. As the rotational inertia in microgrids is low, following a load change(increase or decrease) the system exhibits large frequency deviations. The microgrid should have robust frequency performance for a wide operating range and the control should provide enough minimization of the frequency deviations. This paper presents a micro-grid powered by bio-diesel run synchronous generators.

Renewable Energy Data Book (2013) describes biodiesel as the fastest growing biofuel type, with production increasing by 64% in the United States and 17% globally, from a relatively small base. Biodiesel is made through a chemical process called '*transesterification*' whereby the glycerin is

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separated from the fat or vegetable oil. The process leaves behind two products -- methyl esters (the chemical name for biodiesel) and glycerin (a valuable byproduct usually sold to be used in soaps and other products).

Fuel-grade biodiesel must be produced to strict industry specifications (ASTM D6751) in order to insure proper performance. Biodiesel is the only alternative fuel to have fully completed the health effects testing requirements of the 1990 Clean Air Act Amendments.

As per Fairbanks Morse Engine (2006), applications of biodiesel in Fairbanks-Morse (FM) engines included a DuPage county Illinois facility with a 1.5 MW generator engine, a facility in Story county, Iowa, and even in Alaska powering six 2.3 MW engines.

As per North East Asia Economic Forum (2010), Hawaiian Electric Company, HECO first did a demonstration test in 2011 at Maui Electric Company on 12.5 MW Mitsubishi diesel engine generators. Initially, biodiesel was used for start-up for cleaner emissions and then successfully tested on 100% biodiesel.

This paper introduces an auxiliary signal in the AGC loop to improve the frequency response of microgrid. The real power mismatch following a load change, which is proportional to the inertia of the generator is given to the AGC. Including this along with normal speed control action, the proposed control reduces the frequency deviation making use of local measurements alone.

II. NEED OF ROBUST FREQUENCY CONTROL

Hasan Bevarani (2014) describes the controls of a microgrid as different types, like generation excitation controls, prime mover controls, generator/load tripping, fast fault clearing, high-speed reclosing, dynamic braking, reactive power compensation, Load-Frequency Control (LFC), current injection and fast phase angle control. Of these controls, some are continuous controls and other are discontinuous controls.

The continuous controls are always active and are usually placed at point of generation. They use local measurements and of these Load-Frequency Control plays a vital role as it does the real time power balancing in the microgrid. A high stress on microgrid creating power imbalance between load and generation highly degrades the power system performance (and even stability); this effect cannot be described in conventional voltage stability and transient stability studies.

As per *P.Kundur* (1994) and *Wood* and *Wollenberg (1996)* primary frequency control is a local automatic control that adjusts the active power generation of the generating units and the consumption of controllable loads to restore quickly the balance between load and generation and counteract frequency variations. Thus the frequency deviation is an index of the power imbalance between the load and generation in the particular area. By restoring frequency to the nominal operating value, the system operator restores the power balance also.

If frequency is not restored, the off-normal frequency operation of the system may affect power system operation, reliability, security and efficiency by damaging equipments, degrading load performance, overloading of transmission lines and triggering the protection devices.

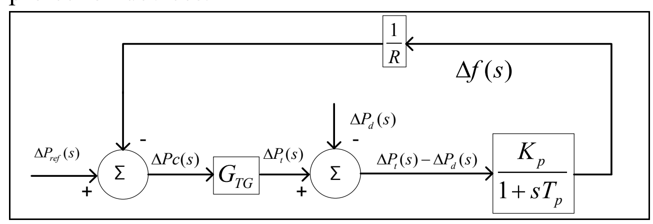

Fig.1. Primary Frequency Control

Fig.1. depicts the primary frequency control; it is called the speed governor and it takes frequency deviation as the input. G_{TG} is the transfer function of Turbine. $(\frac{k_p}{1+sT_p})$ is the transfer function of the microgrid under consideration. R is the speed regulation of the governor. The Primary control alone is not sufficient to bring back the frequency back to the nominal operating value.

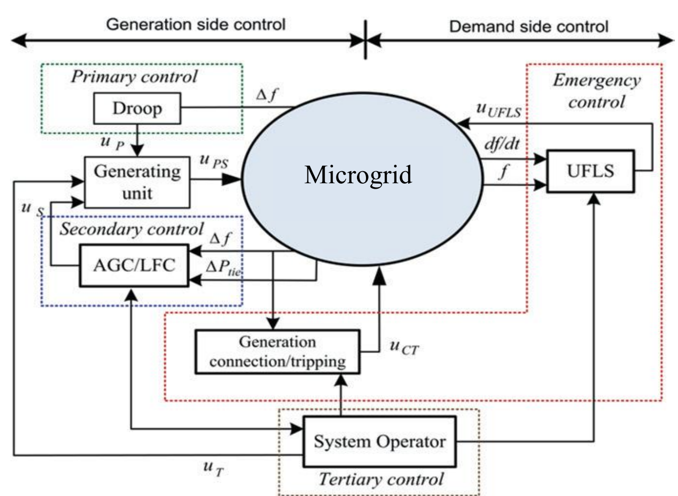

Fig.2. Various types of Frequency controls

As per the UCTE Operation Handbook (2004), the demand side contribution of the frequency regulation, from frequency sensitive loads or frequency sensitive relay is not always taken into account for calculation of primary frequency control response. So, only the generators are assumed to contribute for primary frequency control.