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# Electrical demand side contribution to frequency control in power systems: a review on technical aspects

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ABSTRACT

Demand side participation in frequency control in power systems, which leads to reduced reliance on conventional thermal units in procuring essential control functions of future energy networks, has gained increased developments in recent years. In this context, the aim of this paper is to provide a review on various design and control schemes of electrical load contribution to frequency control algorithms; both centralized and decentralized control structures are discussed in details.

The problem of synchronization of certain types of electrical loads and different proposed methods of avoiding it are also presented and discussed. Synchronization, which is a consequence of collective controllable demand response to system disturbances, might put the power system in jeopardy and cause its failure; therefore, in order to fully comprehend the causes and effects of this phenomenon, an investigation of this event in a power grid with high level of controllable electrical loads is necessary.


**Contents**



## 1. Introduction

The concept of frequency control in power systems is closely related to balance between power generation and power consumption. Hence, a surplus generated power leads to acceleration in synchronous generators' rotational speed and therefore positive power frequency deviation. On the other hand, an increase in electrical demand or equivalently a sudden loss of a generation unit results in a drop in system frequency. Since the security and reliability of the electrical energy network depend intimately on a well-regulated power frequency signal in the system, it is essential to consider and allocate sufficient amount of reserve to be able to cope with power contingencies. The main idea of frequency regulation in power grids is to surpass the source of trouble (i.e. power unbalance) by means of injecting additional amount of reserve to the system. Traditionally, reserve provision in power

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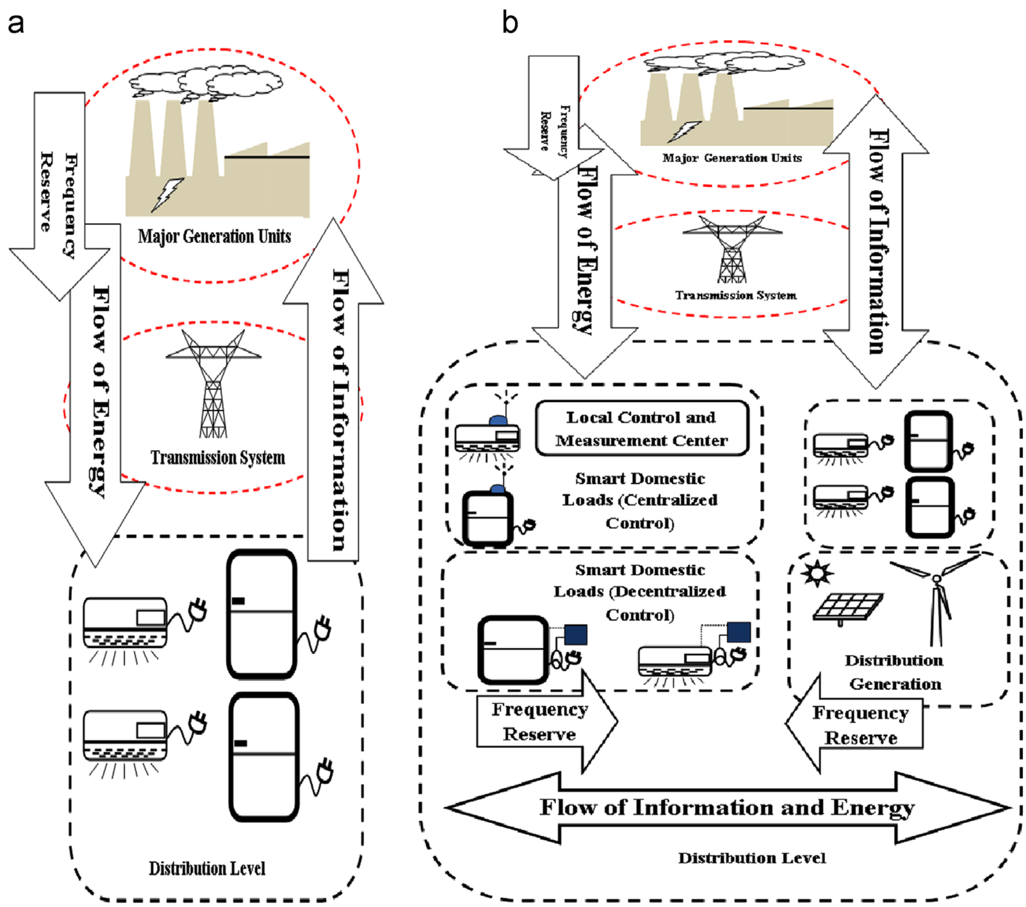


**Fig. 1.** A comparison of energy networks: a) Conventional network with major thermal power generation units. b) Future networks with high penetration of distributed energy resources and smart loads.

systems has been exclusively the duty of generation units; thus, in face of a power contingency, synchronous generators alter their output power according to magnitude and sign of frequency deviation in the system. This alteration process takes place in three, timely decoupled stages, which form three distinct frequency control levels in power system. A detailed review of load-frequency control and reserve provision in conventional power systems is presented in Refs. [1,2]. Here, we only present a brief review of the main ideas and methods.

Primary frequency control (PFC) is the first regulation measure designed to respond to frequency disturbances, right after a contingency takes place. PFC is exerted by speed governors and is local and decentralized by nature (i.e. control action is based on local generator speed measurements). While PFC is quite effective in limiting frequency nadir, because of its proportional behavior (known as droop), it is unable to eliminate the steady states error in power frequency signal [3]. Thus, a secondary frequency regulation is needed to eliminate the steady states error and restore the system to its pre-contingency status. The secondary control level, which takes place minutes after the PFC, is a centralized control algorithm exerted automatically (automatic generation control or AGC) or even manually by a higher control entity in load-frequency control hierarchy (usually the transmission system operator). Various design processes for this level of frequency control are presented in [4]. The third level of load-frequency control is aimed at economical and long-term redistribution of load among generation units.

The three mentioned control levels, provided by major synchronous generators, are sufficiently capable of regulating system frequency, with a satisfactory efficiency, in traditional energy networks; however, it is widely believed that in future power systems, this will not be true. Present power systems are generally comprised of major thermal units with synchronous machines, which bear the task of generating the bulk of required electrical power; the generated power is then transmitted in long distances and brought to the consumers. This typical picture of energy networks, however, has been changed radically and rapidly in the past years. Increasing penetration of renewable energy resources, such as wind power generators and photo-voltaic technology, along with modern electronic and communication devices, have created a turning point in the structure of modern energy networks (Fig. 1). On one hand, addressing environmental concerns, vast employment of renewable resources leads to lesser dependence on fossil fuel as a major reservoir of energy; on the other hand, utilization of modern data processing techniques in a power system establishes a new level of controllability, and more complicated means of energy management. Thus, the concept of “microgrid” is invented to address the advent of future requirements of electrical energy networks.

A microgrid can be thought of as a cluster of small-scale electrical energy resources (distributed generation units) and loads, connected closely together. A microgrid should be capable of stable operation in islanded mode (disconnected from the national grid), which adds to the complicacy of its control and management. Unlike traditional systems, in a microgrid, generation and demand sides are linked to common busses. Thus, any disturbance on either side (stochastic power output, sudden changes in consumption pattern, etc.), directly affects the other side. Hence, stabilizing and management of microgrids is a critical task which requires thorough investigation. However, this paper is