# Control Methods and Objectives for Electronically Coupled Distributed Energy Resources in Microgrids: A Review

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***Abstract*—Increased penetration of distributed energy resources into conventional power systems increases control challenges. These can be suitably met by microgrids. This paper examines the architecture of microgrids and reviews their classifications and the literatures discussing their control objectives during islanded mode. It finds the use of microgrids enhancing the conventional power system's grid smartness. It also summarizes microgrid control objectives and their most common problems and solutions.**

***Index Terms*—Distributed energy resources (DERs), droop method, electronically coupled, load sharing (LS), microgrid control, power converters.**

## I. Introduction

THE POSSIBILITY of increased blackouts in power systems can be due to both economical and physical reasons, e.g., 1) increased demand for power that had to be transferred over long distances, resulting in huge amounts of lost power; 2) continual load growth unparalleled by sufficient investment into power generation and transmission systems; and 3) extreme swings from one day to the next in power flow dispatch, making conventional offline planning useless. These push power systems to their physical limits, with a possibility of compromising grid reliability. A distributed energy resource (DER) is one solution that can reduce the electrical and physical distances between the load and the generator, improve reactive power to enhance grid voltage profile and power quality, remove bottlenecks from distribution and transmission lines, reduce transmission and distribution losses, make better use of waste heat, postpone the necessity to establish new transmission lines and huge power generation plants, and keep carbon emission levels low [1], [2]–[5].

The challenges to having multiple DERs include the following: 1) the current control strategy (CCS) is unable to function during islanded mode because there is no dominant source of energy [6]–[8]. 2) Multiple DERs have multiple power generation characteristics and capacities; therefore, the microgrid needs rapid regulation more in islanded mode than in grid-connected mode [6]. 3) An increased presence of DERs, particularly in a distribution network (whether medium or low voltage), may cause problems such as voltage rise and unstable network voltage and frequency (either during operation of the DERs or upon their sudden tripping) [6], [9]–[11]. Such problems can be solved by microgrids, whose many features include the following:

1) integrating DERs without interrupting public-grid operation, i.e., a lot of DERs can be installed without reforming or rewiring the distribution system [2], [12], [13];
2) enabling power systems to observe and control faults more effectively and to reduce the damage caused by a DER outage, by continually feeding critical loads [4], [11], [14];
3) allowing load shedding and automated switching through control algorithms, to shorten outage and power restoration time, and keeping the faulted section of the distribution line isolated until utility crews locate the fault location [4], [14], [15];
4) allowing to run in either (grid-connected or islanded) mode, according to the economy or a planned disconnection, or to restore the public-grid power quality when it falls below certain standards [12], [16]–[18];
5) improving system reliability and flexibility, through the many options of DERs [2], [13], [19]–[22];
6) using DERs' waste heat to improve generation efficiency [2], [6], [13], [20], [23]–[25].

The microgrid paradigm is that a group of microsources and loads, with some form of energy storage, operate as a controllable system, providing heat and power to local communities [7], [12]. The Consortium for Electric Reliability Technology Solutions (CERTS) [13] showed that clustered DERs, storage systems, and loads can operate in either grid-connected or islanded mode. Factors affecting the choice of the required control and operation strategies of a microgrid include the

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