

Power Sharing Optimization between Grid and Microgrid With Multiple Distributed Generators

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ABSTRACT: In this paper, a micro-grid for optimal operation of Distributed Generators (DGs) power dispatch problem is concerned. Islanding objective while ensuring the stable operation of grid-connected operation is to reduce the cost of fuel. To achieve this goal, the Economic Dispatch (ED) problem and are associated controls. There are obstacles to be considered in this study: the need for load variation i) the existence, non-dispatch able power output of DGs variation ii) the existence, iii) stable islanded operation in two adjacent areas, and iv) the balance between the flow limits. The first three barriers of conventional power systems, which handled the ED problem, apply the change in micro-grids. I) with standard low and ii) with adjustable low: we have two stable islanded operation in accordance with the principles of power-sharing constraints provide a comprehensive creation. The problem is solved using ABC algorithms method, and numerical simulations to investigate the effect of operational cost controls

KEYWORDS: Distributed generator, economic dispatch, islanded operation, micro grid, smart grid

I. INTRODUCTION

Electric power systems have been undergoing profound changes in response to different needs, such as environmental compliance, energy conservation, improved network reliability, improved operational efficiency and customer service. "Smart Grid", "Smart Grid" and "Next Generation Grid" are applied to the grid of the future, in which the electrical infrastructure and intelligent information networks, integrated to meet the above requirements are names. In themeantime, the increasing use of Distributed Energy Resources (DERs), including intermittent renewable sources, representing many challenges for the future grid, especially with regard to the distribution system. In order to solve the connectivity problems of individual Distributed Generators (DG), the concept of a microgrid has been proposed. A microgrid is a low or medium voltage distribution network, consisting of various DGs, storage devices and controllable loads that can be operated either in the grid-connected or island-modes. To date, there are numerous research projects on the design, control and operation of micro-networks around the world, such as the CERTS Microgrid in USA, which performed Microgrid Project of Europe, and the new energy integration test project by NEDO in Japan.

In a central controller and an Energy Management System (EMS) have been proposed the most benefit from the operation of a microgrid as a means of dissipation and increasing the efficiency of the DG-use. The main functions of a microgrid EMS are power and voltage set points for each DG controllers offer to the heat and electrical loads to meet in order to satisfy the operation contracts with the main system, minimize emissions and losses, and provide the logic and control for a fast and stable island during grid faults. To fulfill these functions, a microgrid EMS uses a variety of information, such as local electric and heat demand, weather, the price of electric energy, fuel costs and power quality requirements.

Among the above functions, this paper focuses on the problem of determining the performance of the General References for the optimal operation of a Micro Grid. The optimization of a micro-grid has important differences with

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the case of a large power system and the conventional Economic Dispatch (ED) problem. One of the main differences is the need for stable operation transition of a grid-connected to island operation during grid faults. Therefore, we propose that the formulations of the ED problem for micro-grids and the associated restrictions that result in the fuel cost minimization in parallel with the mains and at the same time stable operation after island.

The rest of this paper is divided into five sections. Section II lists several questions regarding the power control of DGs in a microgrid. In Section III, the economic dispatch problem and related restrictions for a microgrid can be formulated. Section IV, the formulation of the boundary condition for the stable island operation in accordance with the power-sharing principle between the DGs. Section V describes the results of the numerical simulation used to examine the effect of any limitation on the operating costs. Finally, Section VI contains some concluding remarks.

II. TECHNICAL ISSUES RELATED TO MICROGRID ED

Active Power and Frequency Controlling Microgrid

Prior to the development of the formulation of the ED problem for a microgrid, we will briefly discuss some technical problems on the active power and frequency control of the Directorates-General: 1) the power control mode, 2) the power-sharing principle of DGs during Microgrid island and 3) the controllability of the energy sources ,

1) Power-Control Mode:

The power output of a DG can be controlled by one of two different modes: Unit Output Power control (UPC) or Feeder Flow Control (FFC). A UPC mode DG produces a constant active power according to the power reference, while the output of an FFC DG mode is controlled so that the active power flow remains constant in the feed. In this study, the output reference for a UPC-mode DG and the supply current reference for a FFC mode DG by solving the ED problem can be determined with respect to the optimal operation of a Micro Grid.

2) Power-Sharing Principle During Microgrid Islanding:

If a microgrid is disconnected from the main network, the General must take the place of the main grid in adapting the current demand. Studies in many of the performance over frequency Droop control has been adopted in order to ensure that the power requirement is dynamically balanced by the DGs [5] . Conventionally, the static constant of a DG is determined as a fixed parameter, the load demand is the DGs are divided in proportion to their nominal capacity. Proposed in [4] and [5], a new power-sharing principle, where the roof slope constants are modified regularly according to the operating points of the DG units. With this method, the DGs will share power according to their operational reserves, rather than their capacities. Please refer to the previous techniques as solid static and the latter techniques as adjustable droop and formulate the restriction related to the isolated operation of a microgrid in accordance with the principle of power-sharing.

3) *Controllability of Energy Sources:* The emerging generation technologies suitable for microgrid application, together with their typical capacity ranges, are listed in Table I [16]. Since most DGs are interfaced with the grid through an inverter, they have various control capabilities, including power, frequency, and voltage control. However, the power outputs of DGs with renewable energy sources, such as photovoltaic cells and wind turbines, are driven by weather, not by system loads. Therefore, these intermittent sources cannot be used as dispatchable sources. In the ED problem, these sources will be treated as negative loads, and their power outputs will be assumed to be predictable within some range of uncertainty.

Constraints Associated With Micro grid Operation

As Fig. 1 shows the micro-grid configuration in this study as a multi FFC configuration, the most suitable for a micro-grid, in which none of the DGs are dominant [17] is in a position [18]. We assume that the variation of loads and power outputs of non-dispatchable DGs in each control area are fed offset by the Dispatch DGs in the same area. To achieve this, the first DG in each area is in the FFC mode while the others operate in the UPC-mode as shown in Fig. 1 (b). With this configuration, any variation can be compensated for within a plane through the FFC DG mode,

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and the flow between the two adjacent areas remains unchanged over a predetermined time period. This property is advantageous, network operators, as microgrids can be considered as controllable subsystems.

The basic ED problem is extended to the additional conditions for the operation of a micro-grid are based. The constraints in this study are not taken into account as follows:

- i) Reserve for variation in load demand.
- ii) Reserve for variation in the power outputs of non-dispatchable DGs.
- iii) Flow limits between two adjacent areas.
- iv) Reserve for the stable islanded operation.

Since the first three conditions were already adopted as part of the ED problem for conventional power supply systems, they are modified only for use on a microgrid. The unique constraint on the reserve for the stable island operation is discussed in detail in section IV.

III. PROBLEM FORMULATION FOR A MICROGRID

Formulation of the Basic ED problem

In a power system, the primary objective of the ED is to minimize the total generation cost, while satisfying the power balance and generation limits of the units[21],[22]. This can be formulated as follows:

$$\text{Min} F_T = \sum_{g=1}^{N_{gen}} F_g(P_g) \quad (1)$$

$$\sum_{g=1}^{N_{gen}} F_g(P_g) = \sum_{d=1}^{N_{load}} L(D_d) \quad (2)$$

$$P_g^{min} \leq P_g \leq P_g^{max} \quad (3)$$

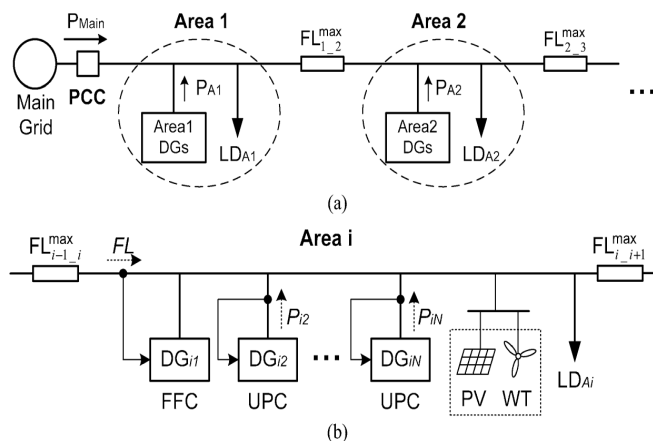


Fig.1. Micro grid configuration.(a) Configuration of a microgrid with multiple control areas.(b) Configuration of a control area

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Modification of the Constraint Formulations

1) Power Balance Constraints:

The current account state is input as modified (4), taking into account the benefits of the not-Dispatch and sources of power from the main grid. The load requirement and the power outputs of the intermittent sources are predicted for each time interval.

$$\sum_{g=1}^{N_{gen}} F_g(P_g) + P_{main} = \sum_{d=1}^{N_{load}} L(D_d) - \sum_{k=1}^{N_{ND}} P_{ND_k} \quad (4)$$

2) Spinning Reserve Requirement Constraints:

Normally there are uncertainties involved in predicting load demand and wind velocity and/or irradiance. Moreover, load demand and the power outputs of intermittent sources usually vary continuously. In order to compensate for these variations, and to operate the system stably, additional reserve is necessary. For a microgrid with the proposed configuration, in which all the variations are picked up by the FFC-mode DG in each area, the constraint can be formulated. The spinning reserve requirement is reflected as a decrease in the maximum limit and an increase in the minimum limit of the first DG within each area. In this study, it is assumed that the load demand varies within of the predicted value, and the power outputs of the non-dispatchable sources vary within of the predicted value.

$$P_{i1} \leq P_{i1}^{max} - \left[\frac{r}{100} \cdot \sum_{d \in A_i} LD_d + \frac{u}{100} \cdot \sum_{k \in A_i} P_{ND_k} \right] \quad (5)$$

$$P_{i1} \geq P_{i1}^{min} + \left[\frac{r}{100} \cdot \sum_{d \in A_i} LD_d + \frac{u}{100} \cdot \sum_{k \in A_i} P_{ND_k} \right] \quad (6)$$

2) Inter-Area Flow Limit Constraints:

As Fig.1(a) indicates, the power flow between two adjacent areas is restricted by the Note that the power flow from/to the main grid is reflected by a decrease/increase in the load on the area nearest the main grid (i.e., area 1), according to (7). Physical limits. This constraint can be formulated as (7)–(10), assuming that the number of areas in a feeder is n .

$$PA_1 = LD_{A_1} - P_{main} + FL_{1,2} \text{ for Area}_1 \quad (7)$$

$$PA_i = LD_{A_i} + FL_{i,i+1} - FL_{i-1,i} \text{ for Area}_i \quad i = 2, \dots, n-1 \quad (8)$$

$$PA_n = LD_{A_n} - FL_{n-1,n} \text{ for Area}_n \quad (9)$$

$$-FL_{i-1,i}^{max} \leq FL_{i-1,i} \leq FL_{i-1,i}^{max} \quad i = 2, \dots, n \quad (10)$$

IV. FORMULATION OF THE CONSTRAINT FOR THE STABLE ISLANDED OPERATION

If a micro-grid island, the DG will adapt their services according to the network frequency droop characteristics to compensate for the loss of the main power. Since the system topology is radial, an output power of each DG change of power flow in the lines will affect upstream. For example, if power from the main grid during grid-connected

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operation imported, the DGs are to improve their performance and thus the upward flow in each line is increased. Accordingly, when the current flow between two areas has remained near its limit at the mains parallel operation, power can not be transferred during the transition, and this may make the system unstable. In load shedding algorithms have been proposed for stable operation in such accidents. However, in this paper, we assume that the DGs are able to supply all loads without restriction during the island operation. For this reason, the General should have at least as much reserve during grid-connected operation. Further, the interface should also be refined yield point in the determination of the power of thereference GDS. The more the flow limits are restricted, the more stable the system will be when island. However, such a restriction is to increase the operating costs during grid-connected operation. Therefore, we propose a method for determining the optimal values of the flow limits that meet the two objectives mentioned above (ie cost minimization for grid-connected operation and stable island operation). This section presents the formulation of this restriction in accordance with each of the two different power-sharing principles (statics fixed and adjustable droop).

Constraint Formulation WithFixed Droop

With this power-sharing principle, eachDG will change its power output in proportion to the inverse of the predetermined droop constant. Since the sum of the power output changes should be equal to the magnitude of, the power picked up by a unit during is landing can be calculated from (11).

$$\Delta P_g^{IM} = \frac{\frac{1}{R_g}}{\sum_{j=1}^{N_{gen}} \frac{1}{R_g}} \cdot |P_{Main}| \quad (11)$$

Similarly, the amount of power shared by are acan be calculated as the sum of the contributions for all the units in area, as follows.

$$\Delta P_{A_i}^{IM} = \frac{\sum_{g \in A_i} \frac{1}{R_g}}{\sum_{j=1}^{N_{gen}} \frac{1}{R_g}} \cdot |P_{Main}| \quad (12)$$

The constraints can be formulated differently, depending on whether the power is initially imported from or exported to the main grid.

- 1) **Power Initially Exported:** When the micro grid supplies power to the main grid during the grid-connected operation (i.e.,), the DGs will decrease their power outputs during the transition. Accordingly, all DGs should have additional down spinning reserve, and this is reflected by an increase in the minimum limit of the unit, as follows.

$$P_g^{min} + \Delta P_g^{IM} \leq P_g \leq P_g^{max} \quad (13)$$

Since the DGs decrease their performance, the downward Flow between areas will increase during the transition. why Fore, for the stable island operation without violation of physical inter-area flow limits, which should be maintained at an appropriate level below the limit during grid-connected operation downwardly directed flow. The amount of the additional flow from area to area is divided downstream of the DGs in area and the areas of the sum of the power. Accordingly, the downward flow limit should be reduced by the amount of additional power while the upward flow limit remains unchanged

$$-FL_{i-1,i}^{max} \leq FL_{i-1,i} \leq (FL_{i-1,i}^{max} - \sum_{a=i}^n \Delta P_{A_a}^{IM}) \quad i = 2, \dots, \dots, n \quad (14)$$

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2) *Power Initially Imported*: If power is imported from the main grid during the grid – connected operation (i.e., $P_{Main} > 0$), the DGs will increase their power outputs when the micro grid is disconnected from the main grid. Contrary to the former case,

$$P_g^{min} \leq P_g \leq P_g^{max} - \Delta P_g^{IM} \quad (15)$$

Constraint Formulation With Adjustable Droop

When fixed droop is adopted, the contribution of each DG to there serve is determined before solving the ED problem ,and thus the output limit of unit is modified according to (13) or (15). However, when adjustable droop is applied, the power output reference for each DG is determined optimally, and the contribution to the reserve is then determined according to its operational margin [14], [15]. Hence, the output limits of the DGs do not need to be modified. The inter-area flow limits, on the other hand, should be refined as in the case of fixed droop.

1) *Power initially Exported*: As was noted in the fixed droop case, the DGs will decrease their power outputs in order to compensate for the loss of the main grid. If we assume that the output of unit is, the operational margin of this unit is. Therefore, the power shared by unit during the transition can be calculated as follows.

$$\Delta P_g^{IM} = \frac{P_g - P_g^{min}}{\sum_{j=1}^{N_{gen}} (P_j - P_j^{min})} \cdot |P_{Main}| \quad (17)$$

As in the fixed droop case, the amount of power shared by area can be calculated as the sum of the contributions regarding all units in area i

$$\Delta P_{A_i}^{IM} = \frac{P_{A_i} - P_{A_i}^{min}}{\sum_{j=1}^{N_{gen}} (P_j - P_j^{min})} \cdot |P_{Main}| \quad (18)$$

V. NUMERICAL SIMULATIONS AND RESULTS

Test System Description and Solution Method

We developed system data to test the ED problem for micro grids, since a suitable benchmark system seems to be currently unavailable. In, a mathematical formulation for the fuel cost function of a PEM fuel cell is introduced, in which the cost is a function of the generated power, efficiency, and fuel price, as given in. The efficiency curve of a fuel cell is determined in as a function of the part-load ratio (PLR, ratio of generated power to maximum power capacity), and the curve is approximated by a fifth-order polynomial, as in. For other DG sources, such as micro turbines and gas turbines, the efficiency is also reduced at part-load conditions, in comparison to the full-load condition [16]. As with fuel cells, the PLR-efficiency curves of these sources

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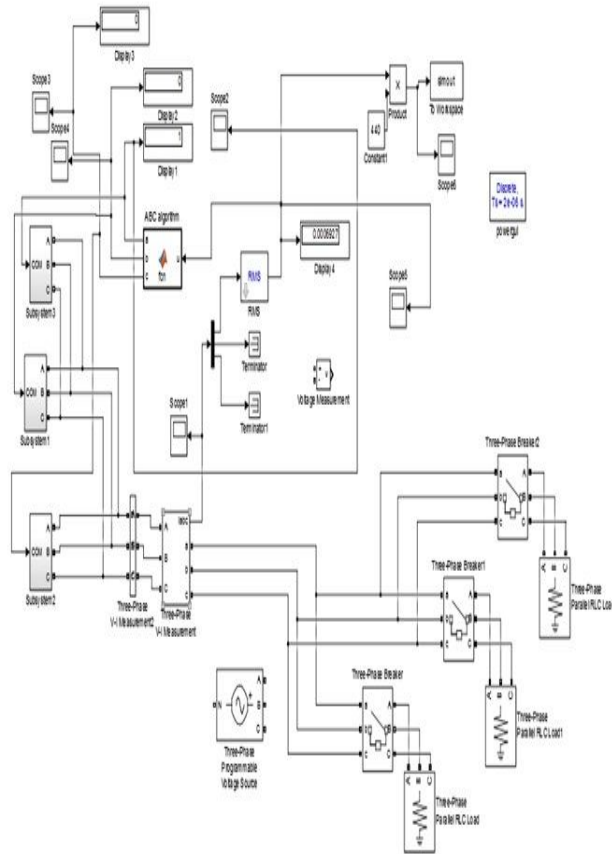


Fig 3 Simulation diagram

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1 was only 25% of the total demand. Therefore, in order for the reduction of the total production costs, the DGs in the range 2 to produce more power than the local load demand, and transfer the excess energy to other areas. For example, in a system load of 1500 kW, 22 kW and about 118 kW of power was transferred to regions 1 and 3 of domain 2. respectively, when the intermediate portion is not limited current. However, as the inter-area yield strength decreases, the power from the region 2 is transferred restricted, and the units in areas 1 and 3 with higher marginal costs should fold their outputs, which also increases the overall production costs IN-.

We can also see that the costs showed a tendency to increase the reserve requirements in terms of load change. The output power of the FFC-DG in each area should be limited to compensate for the load change, in accordance with (5) and (6). Since the marginal cost of the FFC DGs were relatively low, an increase in reserve requirements led to higher production costs. Another observation from Fig. 2 is that the effect of the inter-area yield value was dominant in Case1, while the effect of load variation reserve was critical in Case.

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VI. SIMULATION RESULTS

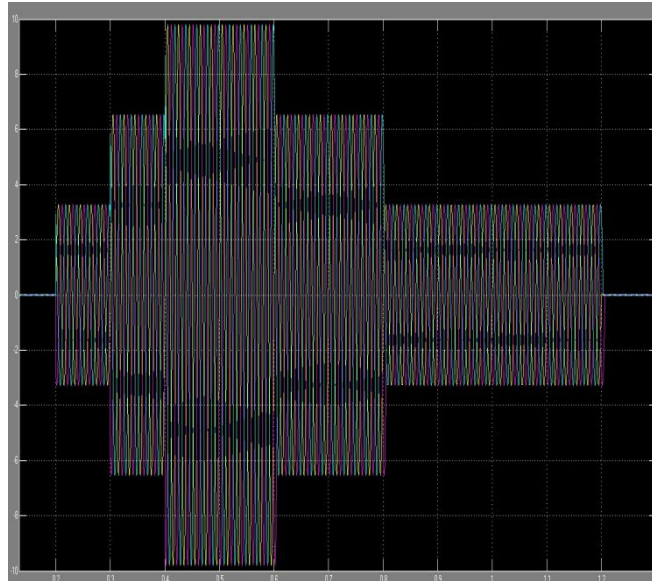


Fig 4 current peak waveform

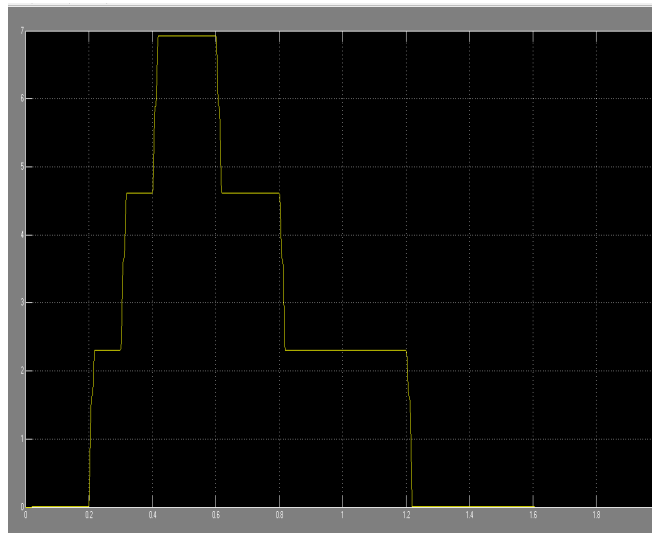


Fig 5 power waveform

VII. CONCLUSION

Sorted according to various constraints related to the economic dispatch problem in a micro grid operation. Some restrictions apply to a micro grid. We structure formulated by modifying the existing regulations to ensure that additional regulation is proposed as a micro grid standard islanded operation, and the DGs. A test method according to the principle of sharing power with the creation of a comprehensive hosted and the area of 15 DG units into account the every one of the load DG source take performance, is developed simulations. We spend (load variation balance, flow range, load distribution method, and the main power grid, including injection) study of the effect of various factors.

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Although the cost increased by up to 0.7%, a micro grid could be operated economically during the grid-connected mode, and soundly during the islanded mode, using the modified dispatch solution, which takes into account the additional constraint.

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