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# Economic Emission Dispatch Problem Solution Using Ant Colny Optimization of Micro-grid in Island Mode

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**Abstract** —*Micro-grids have spread in many distribution systems worldwide. Microgrids are operated by a customer or a group of customers for having a reliable, clean and economic mode of power supply to meet their demand. Furthermore, micro-grids can help in integrating and promoting for Renewable Energy Sources (RES) and reducing the environmental impacts of traditional centralized generation. This paper presents an economic and emission dispatch problem solution using Ant Colony optimization of micro-grids. An isolated micro-grid with solar is considered in this paper. A combined cost optimization scheme is investigated to minimize both operational cost and emission levels while satisfying the micro-grid's load demand. The effects on total generation cost, with the inclusion of solar energy into a micro-grid is studied and found the most profitable solution by considering different practical scenarios. The Ant Colony was implemented using MatLab and tested on two case studies with and without RES-Solar energy (PV). The obtained results from the Ant Colony technique are compared with those calculated using other Techniques; Gradient method. The outcomes are evaluated and discussed.*

***Keywords***- *Micro-grid, Ant Colony Optimization, combined economic emission dispatch, Renewable Energy, Solar Energy, Cost Functions.*

## I. INTRODUCTION

Micro-grids are modern small scale versions of the centralized electricity system, designed to supply electricity for small communities such as villages or commercial areas like industrial factories. They were meant to achieve specific goals such as reliability, and carbon emission and operational cost reduction. Micro-grids have emerged in the electric industry increasingly attracting consumers [1]. Due to increase in the electrical power demand and clean energy, the demand for micro-grid is increasing [2],[4]. Micro-grid operates in both grid connected and islanded mode, at a low voltage with distributed generators, energy storages and controllable loads [3]. The loads can be both critical and non-critical loads. The micro-gird changes to islanded mode from the grid connected mode due to the transmission level maintenance or faults at the transmission feeder [5]. Solar are usually intermittent in nature, so they are considered as negative loads. The two different categories of economic dispatch are power dispatch and heat dispatch. As the heat dispatch is considered constant, this paper mainly focuses on power dispatch only [13].

In this paper, economic dispatch optimization in islanded mode is considered. The Ant Colony technique is implemented to obtain the minimum cost of the system. The main aim of the paper is to implement the economic emission dispatch to achieve optimal cost of the system.

In [6-10], the economic dispatch problems using the Ant Colony technique were evaluated and the results showed better cost savings, effectiveness, and flexibility to solve this problem under study. In [11],[12]. The combined economic emission dispatch problem was evaluated for a mix of conventional and RES using Gradient method.

In this paper, a micro-grids is to solve the combined economic emission dispatch problem using ACO taking into consideration both conventional and RES-PV generation. In Section II, the ACO technique and its enhancement for the economic and emission are illustrated. The economic emission for micro-grids formulation is explained. The combined economic emission dispatch cost function and its constraints are provided in Section III. In Section IV, case studies were carried out. The case studies were implemented to evaluate promotion of RES-PV in micro-grids using the economic and emission to minimize generation cost of the whole system including the PV investment cost. The obtained results are shown and discussed. Finally, conclusions are discussed in Section IV.

## II. ANT COLONY OPTIMIZATION TECHNIQUE

The economic emission dispatch solution was designed using the Ant Colony technique due to its effectiveness and accuracy. Some features were added in the proposed technique to enhance its results [6-7] and decrease its computational time, and they can be explained as follows:

The ant colony search mechanism can be divided into a) initialization, b) transition rule, and c) pheromone trail update rule.

 

A. Initialization

During initialization the parameters such as the requisite number of ants, the relative importance of the pheromone trail, relative importance of the visibility, initial available pheromone trail, a constant related to the quantity of the trail laid by ants, evaporation factor, tuning factor etc… have to be fixed and taken care.

B. Transition rule

The transition probability for the $k^{th}$ ant from one state $i$ to next state $j$ for an ACO model is given by

$$P_{ij}^{(k)}(t) = \begin{cases} \dfrac{[\tau_{ij}(t)]^{\alpha}[\eta_{ij}(t)]^{\beta}}{\sum_{j \in N_i^{(K)}} [\tau_{ik}(t)]^{\alpha}[\eta_{ik}(t)]^{\beta}} & j \in N_i^{(k)} \\ 0 & j \notin N_i^{(k)} \end{cases} \quad (1)$$

Where,

$\tau_{ij}$ is the trail intensity on edge (i, j), $\eta_{ij} = (1/C_{ij})$ called heuristic function, $C_{ij}$ is the production cost occurred for that particular stage, α is the relative importance of the trail $\alpha \geq 0$, β is the relative importance of the visibility $\beta \geq 0$, $N_i^{(k)}$ is the available states $k^{th}$ ant can choose from $i^{th}$ state to $j^{th}$ state.

C. Pheromone trail update rule.

- *Local Updating Rule*

During the establishment of its tour, an agent changes the amount of pheromone level on the visited path applying the local updating rule,

$$\tau_{ij} = (1-\varsigma)\tau_{ij} + \tau_0 \quad (2)$$

Where; $\varsigma$ is the heuristically defined parameter, $\tau_0$ is initial pheromone level,

The local updating rule is intended to shuffle the search process. Therefore the desirability of paths can be dynamically changed. Every time an agent uses a path it becomes slightly less desirable, since it losses some of its pheromone. This allows agents to make a better use of pheromone information.

- *Global Updating Rule*

When all the agents have built their individual solution the global pheromone-updating rule is applied only to paths that belong to the best agent tour. In other words, the pheromone-updating rules are designed so that they tend to give more pheromone to paths that are visited by more agents. The pheromone level is updated by applying the global updating rule,

$$\tau_{ij} = (1-\rho)\tau_{ij} + \rho\Delta\tau_{ij} \quad (3)$$

Where, ρ is the pheromone decay factor ($0 < \rho < 1$).

## III. ECONOMIC EMISSION DISPATCH FOR MICRO-GRIDS

Economic emission refers to an efficient and effective use of energy to minimize cost, improve energy efficiency, and reduce greenhouse gas emissions by making use of RES and reducing the impacts of blackouts or interruptions in energy supplies.The combined economic emission dispatch problem in a typical micro-grid by providing hourly active power generation set-points while satisfying the load demand. It aims at minimizing operating cost and emissions. The economic emission dispatch was designed using ACO technique in the MatLab environment.

A. The optimization cost function:

The combined economic dispatch problem is addressed as a single optimization problem with respect to fuel cost and emissions function as follows:

Min Ft = Fuel Cost Function + Emission Function

- *Fuel Cost Function*

The generator fuel cost function is represented as a quadratic equation and can be expressed as follows:

$$F_C = \sum_{i=1}^{N} a_i + b_i P_i + c_i P_i^2 \quad (4)$$

Where: $F_c$ is the total fuel cost, N is the number of generators, $P_i$ is the real output generation of the $i_{th}$ generator, a,b,c are the cost coefficients $i_{th}$ of the generator

 

- Emission Function

The total emission of atmospheric pollutants caused by operation of fossil fueled generators can expressed as follows:

$$E_T = \sum_{i=1}^{N} \alpha_i + \beta_i P_i + c_i P_i^2 \tag{5}$$

Where: $E_T$ is the total fuel cost, N is the number of generators, $P_i$ is the real output generation of $i_{th}$the generator, a,b,c are the cost coefficients $i_{th}$of the generator.

Therefore, the combined economic emission dispatch problem is formulated as a single optimization problem as follows:

$$Min(F_t) = \sum_{i=1}^{N} [(a_i + b_i P_i + c_i P_i^2) + h_i(\alpha_i + \beta_i P_i + \gamma_i P_i^2)] \tag{6}$$

Where; hi is the price penalty factor which is the ratio between the maximum fuel cost and maximum emission for each generator given by [11],[12].

B. The Constraints:

The combined economic dispatch problem is constrained by power balance and inequality constraints of a micro-grid.

- *Power Balance Constraint*

Total power generation must satisfy the load demand plus the power transmission losses at any given time. The power balance equation is illustrated as follows:

$$P_d = \sum_{i=1}^{N} P_i$$

Where; Pd is the total load demand.

- *Inequality Constraint*

Total power generation for each unit lies between minimum and maximum limits. The inequality constraint can be described as follows:

$$P_i^{\min} \le P_i \le P_i^{\max}$$

## IV. SIMULATION RESULTS

In this section, case studies were carried out. The case is used to evaluate proposed multiple environment dispatch problem to promote for RE-PV investment in Micro-Grids. The micro-grid under study is assumed to be working in the island mode. Thus, there is power exchange with the main grid (selling/buying).

- Economic Emission dispatch-ACO Technique for Promoting RE-PV in Micro-Grids

In [13], a renewable based micro-grid was modeled and an optimization process was carried out using the Gradient method technique with respect to the total generation cost of the whole system without/with RE-PV.

A comparison was made using the same coefficients and constraints with the ACO technique to include RE-PV into consideration. A case study was carried out to satisfy a daily load profile shown in Table I. The micro-grid model is assumed to have three conventional generators and a non-dispatch-able PV generator. The generators power limits and cost and emission coefficients are described in Tables II and III and IV. In this case we have considered the solar data of a location in the east coast of USA, as shown in Fig.1.

TABLE I. LOAD DEMANDS OVER 24 HOURES PERIOD

| **Time (Hrs)** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| **Load (MW)** | 140 | 150 | 155 | 160 | 165 | 170 | 175 | 180 |
| **Time (Hrs)** | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| **Load (MW)** | 210 | 230 | 240 | 250 | 240 | 220 | 200 | 180 |
| **Time (Hrs)** | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| **Load (MW)** | 170 | 185 | 200 | 240 | 225 | 190 | 160 | 145 |

TABLEII. GENERATORS MAX-MIN POWER LIMITS

| | Max Power (MW) | Min Power (MW) |
|---|---|---|
| G 1 | 150 | 37 |
| G 2 | 160 | 40 |
| G 3 | 190 | 50 |

TABLE III. GENERATORS FUEL COST COEFFCIENTST

| | a ($/hr) | b ($/hr) | c ($/hr) |
|---|---|---|---|
| G 1 | 1530 | 21 | 0.024 |
| G 2 | 992 | 20.16 | 0.029 |
| G 3 | 600 | 20.4 | 0.021 |

TABLE IV. GENERATORS EMISSION COST COEFFICIENTST

| | α($/hr) | β ($/hr) | γ($/hr) |
|---|---|---|---|
| G 1 | 0.0105 | -1.355 | 60 |
| G 2 | 0.008 | 20.16 | 45 |
| G 3 | 0.012 | 20.4 | 30 |

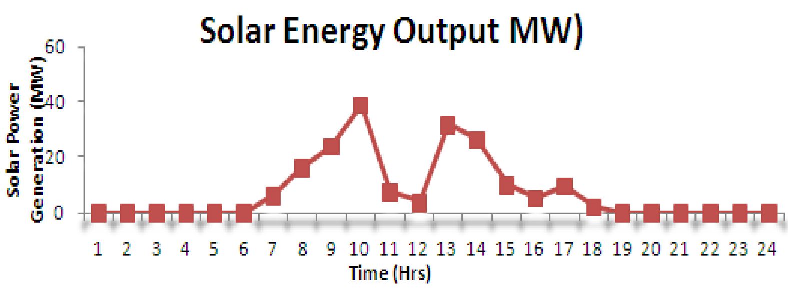


Fig. 1 A Daily PV Power Generation

Two scenarios were carried out:

- Scenario-1: Three fueled generators:

The ACO technique was implemented to minimize the combined economic emission dispatch problem, equation (6). The obtained results were obtained for a daily load demand and it was compared with the results obtained by the Gradient method and reported in [13]. Fig 2, and Fig 3, shows the generation dispatch of the three generators and the total operating cost without and with emissions cost. Results show that the ACO technique saved 0.61% (no emission cost) and 4.50% (considering emission cost) over the Gradient method in total cost. Moreover, for the gradient method, the reported dispatch power are taken from [13] without taking the emission impact into consideration. Then, the emission cost is calculated based on the optimized dispatched generation without emission consideration. However, the proposed ACO technique, dispatch problem used equation (4) or (6) for no emission or emission cost consideration respectively.

 

- Scenario-2: Three fueled generators and one PV generator:

According to the worldwide practice for RE generation/transmission, RE has priority to be transmitted as soon as it is generated over fossil fuel generated electricity. Therefore, the PV generated power can be considered a negative load and used to reduce the load demand values. The rest load is supplied from the conventional generators in the system where the economic dispatch problem is used. The ACO is carried out to solve the combined economic emission dispatch problem taking into consideration the RE-PV investment cost. The aim is to minimize the total generation cost of the system. Cost function for the PV generator considers the investment cost of the equipment and the operation and maintenance cost. The cost function can be described as follows:

$$F(P_S) = aI^p P_S + G^E P_S \qquad (7)$$

$$a = \frac{r}{1-(1+r)^{\wedge(-N)}} \qquad (8)$$

Where; Ps is the solar generation, a is the NPV coefficient, r is the interest rate assumed to be 9%, N is the investment lifetime assumed to be 20 years, lp is the investment cost per installed power ($/KW), $G^E$ is the operation and maintenance cost per unit generated energy ($/KW).

The obtained results, Fig 4, and Fig 5, show the proposed power ($/KW), ACO technique saved 0.62% (no emission cost) and 4.45% (considering emission cost) over the Gradient method reported in [13] of total cost. In the meanwhile, comparing the ACO results in Fig.3 and Fig.5, installing RE-PV in the micro-grid saved 2.65% of the total system cost despite of the high PV investment cost taking into consideration the emission cost of conventional generation.

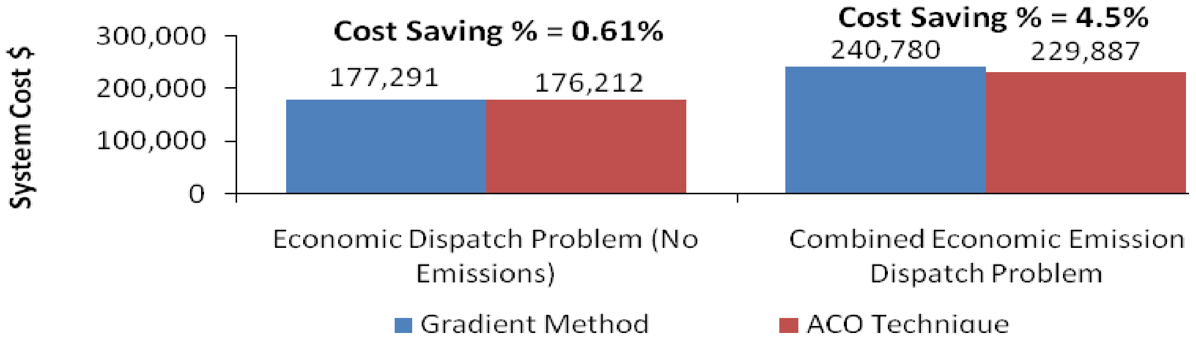


Fig.2 Comparison of Total Generation Cost Using Gradient Technique and ACO Technique (without-PV)

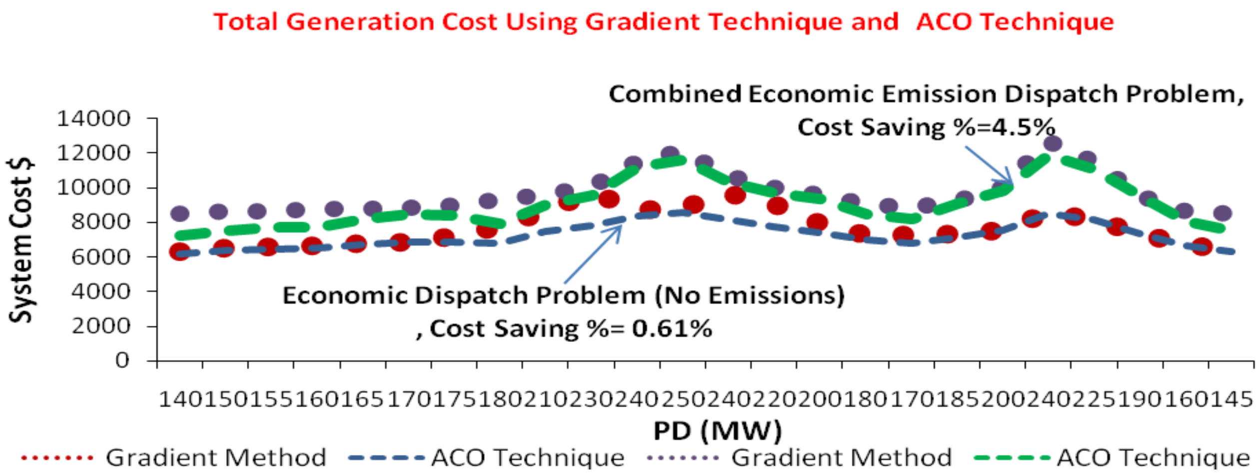


Fig.3 Total Generation Cost Using Gradient Technique and ACO Technique (without-PV)

 

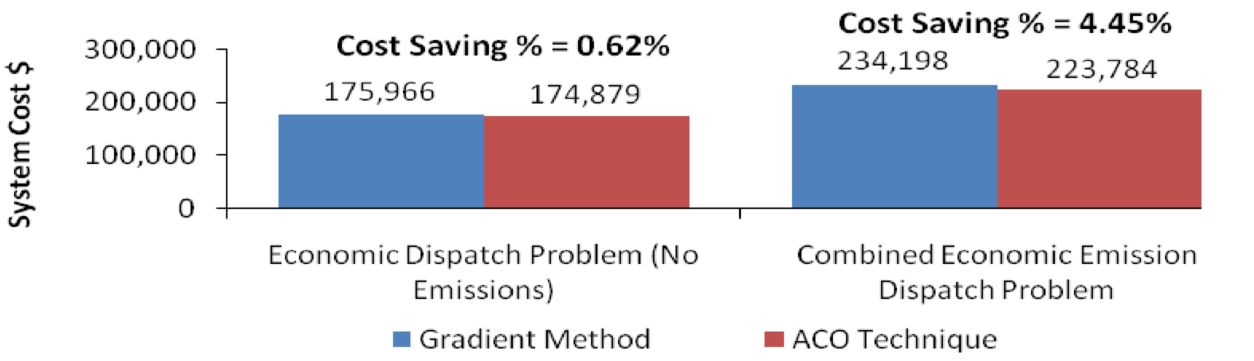


Fig.4 Comparison of Total Generation Cost Using Gradient Technique and ACO Technique (with-PV)

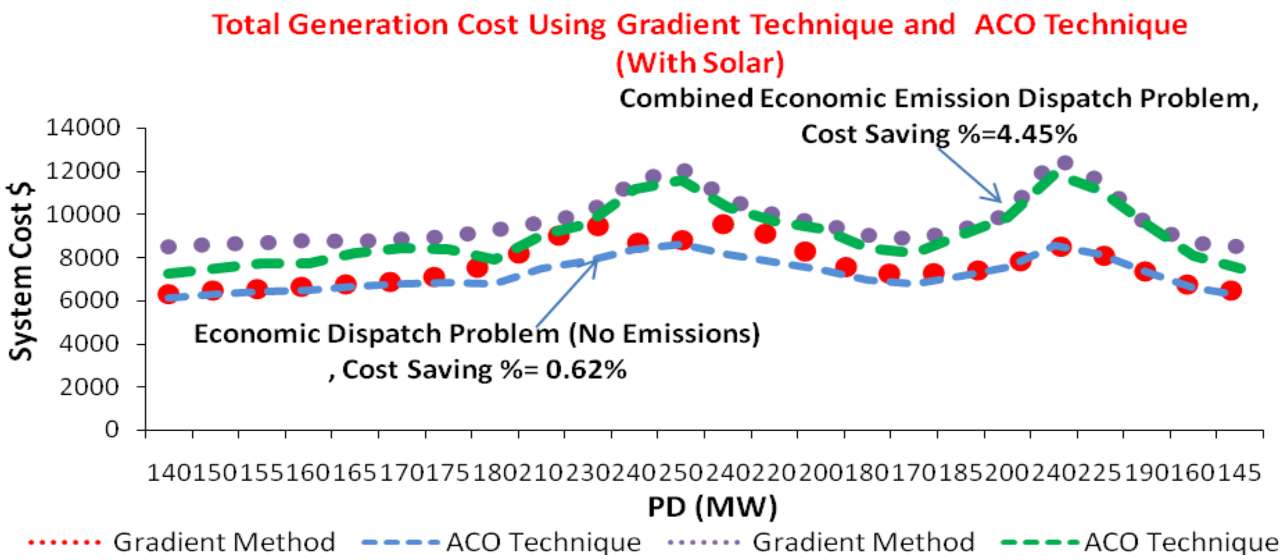


Fig.5 Total Generation Cost Using Gradient Technique and ACO Technique (with-PV)

## V. CONCLUSIONS

This paper presents solution for a micro-grid with and without RES-PV to solve the combined economic emission dispatch problem. The economic emission dispatch solution was designed using the Ant Colony technique and tested on different case studies. In the case, micro-grid without/with RE-PV, the ACO technique was compared with Gradient method. Results show that the ACO technique saved 4.50% over the Gradient method taking emission cost into consideration without RE-PV in the micro-grid. However, considering RE-PV, the ACO saved 4.45% over the Gradient method considering the emission cost as well. In the meanwhile, results show that investing in RE-PV has saved 2.65% of the total generation cost in the system taking into consideration the PV investment cost inspite of its high capital investment. In a nut shell, the ACO technique offered cost savings for the combined economic emission dispatch problem in all cases allowing more efficient management on the given micro-grids. Furthermore, it showed that investing that investing in PV can save the system running cost of the conventional Running cost of the conventional generation in the micro-grid which leads to promote PV investments in micro-grid.

 

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