FORMULATION OF PRICING MECHANISM FOR MICROGRID ENERGY

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ABSTRACT

Interconnection of various low voltages, small-scale distributed generators (DGs), energy storage devices and controllable loads interfaced through fast acting power electronic devices in an isolated remote area forma a microgrid as islanding operation where conventional grid is not available. Combined heat and power (CHP) produced by DGs may be utilized in the local market making the Micro grid most efficient and economic. Like deregulation regime in conventional power market, multi agent generator providers also may be considered to make the Microgrid market equal competitive. The basic objective of a competitive electricity market is to serve the consumers at a reduced price. The objective of this paper is to analyze and propose the pricing mechanism for Microgrid energy in the competitive electricity market where the Microgrid Central controller (μcc) is made to participate in the bidding process to finalise pricing mechanism). Two important market settlement techniques, Day-ahead and Real-time, have been considered with the marketing strategies of renewable DGs like Photovoltaic (PV) and wind generation introduction

INTRODUCTION

UNBUNDLING is happening very fast in electricity sector since last decade , onwards to decentralise the control in all three section of Power systems like Generation, Transmission & Distribution to a distributed control regime in all over world especially in the geographically remote areas where erection of conventional grid network either not feasible or economical.

Microgrid is a concept where local energy potentials in remote areas, both in renewable (such as small wind, PV, etc.) and non-conventional (micro-turbine, Fuel cells, Diesel generator) resources, are tapped and interconnected among themselves to form a LV utility system. These small DGs have different owners, supply loads locally with the help of local controllers (μc). μC takes decisions – scheduling of

Generation as per load forecast (i.e., unit commitment) and Economic dispatch of connected with each DG and Microgrid Central Controller (μcc). In the islanding operation of Microgrid, each source caters only those loads, which are stipulated for the source. But when these sources are connected with the micro grid, which is most desirable, and then the action of the controllers (both μ c and μcc) should have a certain degree of intelligence for participation in the common and competitive market.

The purpose of the Energy Management System (EMS) in the Microgrid scenario is to make decisions regarding the best use of the generator for producing Electricity and heat i.e. combined heat and power (CHP) operation. Such decisions will be based upon the heat requirements of the local establishments, the climate, the price of electric power, the cost of fuel and many other considerations. The central controller (μcc) acts as a main operator to take decisions regarding the supply of CHP services to be provided as per demand. Like deregulated regime in the conventional utility grid, multi-agent generating providers are considered in the Microgrid system.

The main idea of this paper is to determine the pricing mechanism at the common BUS levels to facilitate the supply & demand of an aggregated group of different kinds of DGs and an aggregated group of different kinds of consumers respectively. These consumers are categorized as controllable loads (which can be shed) and uninterruptible loads.

An electricity market is a system to affect the purchase and sale of electricity using supply and demand to set the price as discussed below:

Reducing the price paid by consumers for electricity is invariably the first reason given for introducing competitive electricity markets. Microgrid operates in a local market and usually cater to the customers of medium sizes (such as, commercial complex, small industries etc.) and residential. These customers do not have the financial incentives and the expertise required to contribute effectively in the price matter to such a complex local market. Possibly as a consequence of this lack of representation, most electricity markets do not treat consumers as a genuine demand side capable of making rational decisions, but simply as a load that needs to be served under all conditions.

RULES FOR FORMULATION OF PRICING MECHANISM OF MICRO GRID ENERGY

There are three important pricing rules for electricity auction, but only two of them are generally used in real-time markets – (1) uniform or single price market clearing rules and (2) discriminatory or pay-as-bid market clearing rules. First one is very common in electricity market. In this process, sellers would receive the market price for their electricity, even if they bid less than that price and all consumers would pay the market price, even if they bid more than that price. The theory behind such a biding system is that all bids to sell electricity would be priced at the marginal cost of that electricity. As per the second rule, every participant with winning bid pays or is paid at the price of his bid. In this system, bidding is made by guessing the cut-off price, not on marginal cost. There is mistake in guessing from observing the results of the hourly bids, twenty-four a day. Some lower cost firms would guess incorrectly and bid above the cut-off price. Thus, some high cost firms would generate and lower cost firms would remain idle. Cost of generation would, therefore, be increased above the market clearing cost. Pay-as-bid system could be expected to increase the total cost of generating electricity and would therefore be less efficient than uniform market clearing system. With the introduction of deregulation in the power sector, the implementation of the uniform pricing system came as a natural choice, since it is believed to offer to the bidders the incentives to reveal their true cost.

FORMULATION OF PRICING MECHANISM OF MICRO GRID ENERGY

The Market price is the lowest price obtained at the point of intersection of aggregated supply and demand curves. At this price both suppliers of generation and customers are satisfied and would provide enough electricity from accepted sales bids to satisfy all the accepted purchase bids. The sales bids are usually arranged from the lowest offer price to the highest offer price, i.e., in the bottom-up order. Whereas purchase bids are arranged from their highest offer price to the lowest offer price, i.e., top-down order. At that point, the total sales bids would be equal to the total purchase bids.

In a market, both the supply and demand bids are of the same type, i.e., either block or linear bids. Authors have tried to formulate the pricing mechanism of micro grid energy in the competitive market for linear bid cases.

(a) SINGLE SIDE BID MARKET:

In this market supply companies participates in the bidding. And demand of the consumers is considered as constant whatever the market price is. Authors have considered a market comprising of CHP generators (e.g., micro-turbines, fuel cells, etc.), renewable generators (e.g., wind, solar), and diesel back-up generators. Diesel generator is generally used as back up but for comparison purpose it has been taken with the mainstream generators.

Q1 (p) = KW generated by bidder-1 (say, micro-turbine) at a price 'p' $/kWh = Q1elec + Q1Th

as follows:

Q1 (p) = Q1elec + Q1Th

Where:

- Q1 (p): kW generated by bidder-1 (say, micro-turbine) at a price 'p' [$/kWh]
- Q1elec: electrical kW generated by microturbine
- Q1Th: thermal load generated by micro-turbine converted to equivalent electrical load, using Joule's constant.

$$Q_1(p) = \frac{p}{m_{s1}} \qquad \text{……………………………..} \qquad (1)$$

Where m_{s1} is the slope of the linear supply curve of bidder-1. Similarly,

$$Q_2(p) = \frac{p}{m_{s2}} = \text{Q2elec} + \text{Q2Th} \qquad \text{…………. (2)}$$

Where Q2 (p) is KW generated by bidder-2 (say, fuel cell) at a price ‘p’ $/kWh

Likewise, combined supply curve for ‘N’ bidders will be

Q (p) = Q1 (p) + Q2 (p) +……… Up to N

$$= \frac{p}{m_{s1}} + \frac{p}{m_{s2}} + \text{………………}$$

$$= P \sum_{j=1}^{N} \frac{1}{m_{sj}} \qquad \text{………………………………. …. … (3)}$$

As demand is fixed at ‘D’ (say), therefore at the market clearing price (p*),

Q (p*) = D

$$P^* \sum_{j=1}^{N} \frac{1}{m_{sj}} = D$$

$$P^* = \frac{D}{\sum_{j=1}^{N} \frac{1}{m_{sj}}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

In the equation (4), it is assumed that bidders have enough capacity of generation. If the capacity limit – both minimum generation (Q_{min}) and maximum generation (Q_{max}) – is specified then the combined supply curve (3) can be represented as,

$$Q(p) = p \sum_{j=1}^{N} \frac{1}{m_{sj}} [U(Q - Q_{min}) - U(Q - Q_{max})] \ldots\ldots (5)$$

Where functions

$U(Q - Q_{min}) = 1$, When $Q >= Q_{min}$;
$= 0$, When $Q < Q_{min}$;

And

$U(Q - Q_{max}) = 1$, when $Q >= Q_{max}$
$= 0$, when $Q < Q_{max}$

Equating (5) with the demand 'D', the market-clearing price (p*) can be determined.

(b) DOUBLE SIDE BID MARKET:

In this market, elasticity of demand curve has been considered. Both supply side and demand side bidding are taken into account for determination of market clearing price (p*). Both linear supply and demand variations with price have been considered for analysis.

D (p) = combined demand at price 'p' \$/kWh obtained from bids of N numbers of consumers participating in the market

$$= \sum_{j=1}^{N} \frac{p_0}{m_{dj}} - \sum_{j=1}^{N} \frac{p}{m_{dj}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

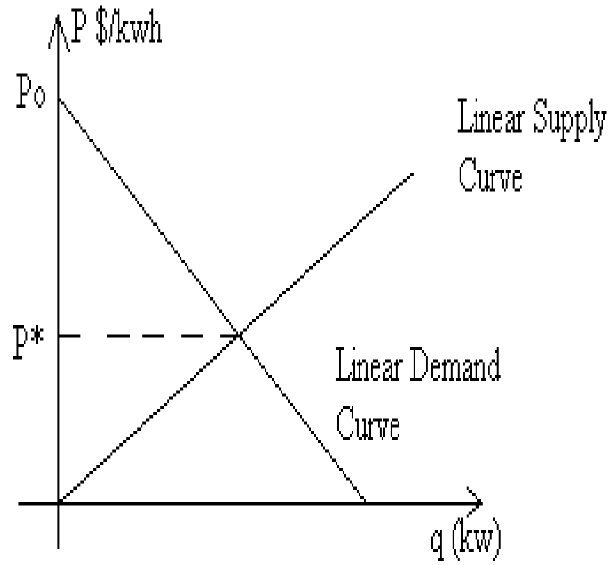

Fig. 2 Linear Demand and supply bid curves

Where *P*o is the price axis intercept of demand curve varies with type of consumers. If at a particular price (p), D (p) is considered aggregated demand for all the participating consumers, therefore

$$D(p) = \sum_{j=1}^{N} \frac{p_0}{m_{dj}} - P \sum_{j=1}^{N} \frac{1}{m_{dj}} \qquad \ldots\ldots\ldots\ldots (7)$$

At the (p*),

$$P^* \sum_{j=1}^{N} \frac{1}{m_{sj}} = \sum_{j=1}^{N} \frac{p_0}{m_{dj}} - P^* \sum_{j=1}^{N} \frac{1}{m_{dj}} \qquad \ldots\ldots\ldots (8)$$

$$P^* = \frac{\sum_{j=1}^{N} \frac{p_0}{m_{dj}}}{\sum_{j=1}^{N} \left(\frac{1}{m_{sj}} + \frac{1}{m_{dj}} \right)} \qquad \ldots\ldots\ldots (9)$$

PRICE INFORMATION IN MICROGRID MARKET

Cost incurred in production of electricity is solely dependent of type of technologies and fuel used for electricity production. On short term electricity market, price of electricity is affected by the cost structure. Marginal costs are mainly the fuel costs.

The DG units which use natural gas (micro-turbine) or diesel have the higher marginal costs and these plants are called the price setting units. Where as mini hydro plants has a low marginal cost.

Electricity can not be stored as well as there is no alternatives to electricity for consumers to react to the price signal. These two points lead to an inelastic demand curve (as shown in Fig. 3). Hence, market price depends on the structure of the supply curve. Thus a threat to strategic price hikes, when some sellers withhold their plants during periods of high demand.

In case of renewable sources, the current cost of buying energy is relatively lower, no fuel and operational cost are involved, compared to the capital cost of buying a wind turbine or PV module. Economic analyses in these cases are performed using simple payback period. CO_2 emission is absent and incentive due to 'no carbon emission' is added advantage.

Electricity can be produced in many ways using a variety of fuels and applying different technologies. This diversity also results in different cost structures. These differences in cost structures have important implications for the price formation on short-term electricity markets. The supply curve is a result of the different cost structure of the DG (Distributed Generation) units. On competitive short term markets prices are set by the short run marginal cost of the DG producing the last unit of electricity required to meet demand. Marginal costs are mainly the fuel costs and some other, less substantial, variable production costs. The last, or marginal, unit needed to meet demand is also the one with the highest short run marginal cost of all units running at a given point in time. The logic of this process ensures that only those power plants operate that have the lowest marginal costs among all generation units available to operate. As a consequence, it can be expected that wind, solar & small hydro units will be dispatched continuously and serve as base load units, so long as availability is concerned. Together with CHP & micro-turbines, these units are listed on top of the so-called merit order list, which means the marginal costs are low compared to other plants (left part of the supply curve). The marginal and therefore price setting units are fuelled by natural gas (right part of the supply curve). The marginal cost of the price setting unit determines not only the revenues of the owner of the DG plant, but also of all other operators with e.g. CHP, wind or small hydro units.

Each consumer may have low and high priority loads and send separate bids to the μcc for each of them. μcc of Microgrid system may be considered as an energy exchange where number of utility providers (private agents) is attached. These agents prepare their unit commitment schedule beforehand and send their bids to the μcc 15 minutes or 1 hour ahead. According to the bids customers let know to the μcc which of his low priority loads are to be shed. μcc in turn send signal to the μc in order to interrupt the supply to those loads.

CONCLUSION

This paper is to formulate the pricing mechanism of microgrid energy at various combinations of non-conventional (i.e., RESes) and conventional energy sources. With the uncertain availability of RESes, it becomes difficult to find out actual market at which trading is to be done. For this, the RESes have been considered, in one case, participating in the market as and when available basis. This paper could guide market researchers with an idea of Microgrid energy market comprising of RESes.

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