

Integration of Standby Generators into Distributed Generation Systems

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Abstract—This paper evaluates a plan for integrating standby generators into distributed generation systems. The standby generators considered in the proposed plan are small generators owned by residential and commercial consumers. These units are, in most cases, used only in the event of utility supply failure, for very short periods of time, and, with very few exceptions, run isolated from the grid. The proposed plan is shown to possess considerable potential benefits both for the owners of these generators as well as for the utility or generating company. The plan consists of operating these generators in parallel with the grid, and the potential problems of this approach are also recognized.

I. INTRODUCTION

Recent experience with wholesale competition in the electric industry has shown that there is significant shortage of generating capacity in many parts of the country. A noticeable rise in the frequency of outages has also prompted a large number of consumers, both commercial and residential, to acquire standby generators. It has been recognized [1] that there is enough capacity available from standby generators to mitigate the capacity shortage experienced by the grid. However, except in those rare cases [2] where the utility takes the initiative to enlist the services of some of these standby generators, they are required, by the electricity code, to run in isolation from the grid. The reasons for doing so are justifiable; moreover, in the past, there has been no compelling reason to challenge these practices. However, the situation has changed. The time has come to change some of these rules. References [1] and [2] have provided some arguments to support this need; this paper proposes a strategy for making it profitable both for suppliers as well as for owners of the standby generators, while at the same time benefiting the grid. In the following sections, the strategy is described, the challenges are enumerated, and some solutions are proposed.

II. BACKGROUND AND MOTIVATION

Most parts of North America have witnessed significant growth during the present times. One of the outcomes of this growth has been in the increase in the use of standby generators to support certain critical facilities. Conventionally these generators are idle for most of the time waiting for an occasional outage to occur. However in spite of this they do generate a continuous stream of operating and maintenance

expenses for their owners. It is not hard to see that these assets are heavily underutilized in the contemporary energy market. This paper suggests some ways to more efficiently utilize them.

In today's competitive energy market the race is on to bring down the prices, utilize resources to their maximum extent, and to maximize profits. This has resulted in very efficient management on the supply side of this business. However it's the demand side that yet remains untapped. The market would only improve if the consumers actively participated in it. Utility companies have implemented various schemes in order to encourage the consumer to take part in the business. They offer incentives to consumers to reduce their demand at the periods of peak prices. However this remains far from sufficient.

Stocking various commodities can dampen their price variations. As of today the storage of electricity has for most part been a pie in the sky causing their procurement costs to vary widely. Most utility companies as of today charge their consumers a flat rate. However their procurement costs are anything but flat. The procurement of electricity is typically carried out through two markets namely the day ahead market (DAM) as well as the real time market (RT). In the DAM the energy prices for each hour of the subsequent day are determined. In this market the prices are comparatively stable as well as lower than those in the real time market. On the other hand in the RT the prices are often determined over much smaller intervals of time and price volatility is considerably higher than in the DAM. Various alternatives have been evaluated here for the substitution of the consumer-generated power in the energy markets.

The plan proposed in this paper consists of utilizing customer owned standby generators for both energy and capacity and compensating their owners appropriately. The potential revenue for both energy and capacity is evaluated and viability of the scheme is examined.

III. CHALLENGES TO PARALLEL OPERATION OF STANDBY GENERATORS

The proposed strategy requires the connection of standby generators to the grid. At the outset we need to acknowledge that a number of challenges arise from this. The major issues are as follows:

- (a) The most important issue is safety. A feeder that the utility may have deenergized for maintenance could still remain energized on account of a standby generator being online at the customer end. This would be extremely dangerous for the maintenance crews.

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- (b) Protection and metering issues could arise from reverse power flows in the distribution feeders.
- (c) Most small generators do not produce an exact sine wave and therefore introducing harmonics in the system.
- (d) The price of conventional synchronizing devices may be a few thousand dollars. This may at times be more than the cost of the generators themselves.

We are in the process of developing highly economical synchronizing devices. These will be interfaced with communication systems that will enable the utility to remotely start and synchronize a generator, monitor it, and meter its generated energy. This form of communication and monitoring will take care of the safety issues. A large part of the power generated by standby generators will be consumed locally, so the reverse flows and harmonics will be small. We do not intend to say that the problem will not exist, but that they will be more manageable.

Reference [2] documents an instance where a utility chose to connect a large standby generator to the grid. Our experience shows that there are utilities that are open to the possibility of considering interconnections of even smaller generators. It is not unreasonable to assume that the code will be modified in the future given the potential benefits of such interconnection.

IV. DESCRIPTION OF PROPOSED STRATEGY

As mentioned above these devices will be capable of (a) synchronizing the generator with the grid in response to a signal issued by the operator; (b) to switch it off when no required (c) record the generated energy and time of use.

Alternatively it maybe possible to automate the start and stop signals to the device when the spot price exceeds a predetermined threshold. It is relevant to mention here that such a device has been partly developed here in our lab. Further development is currently in progress.

This plan calls upon the customer to install a device that will be able to interconnect the generator to the grid. This device would be controlled automatically and remotely. It could be set in order to be able to start generating when the spot price would exceed a certain threshold. It's of importance to be mentioned here that such a proposed device has been designed and tested here in our labs.

Many papers have proposed the utilization of standby generators to address the capacity shortage in some parts of the country [1], [2] but they involve larger standby generators (50 kW or larger). This paper proposes a program that also utilizes smaller generators (3-12kW range) and examines the viability of this approach.

It should be noted that in the following evaluation we have made the assumption that the market prices would not be significantly altered due to the proposed plan. We argue that this assumption is valid due to the fact that the total size of these generators is significantly smaller than that traded in the market. In other words we assert that implementation of the proposed plan will not distort the market behavior.

V. EVALUATION OF THE PROPOSED STRATEGY

In this section we examine the potential revenue the generator owner can get by making the generator available to the grid. At this time the cost of the interconnection device is not taken into account. We will similarly examine the potential revenues from energy and capacity.

A. Revenues from sale of energy

Let us first examine the revenues earned by running a generator only while the market price of energy exceeds the fuel cost of generation by that particular generator. The generator is assumed to be compensated at the prevailing market price. We will consider a sample cross section of generators as listed in Table I.

TABLE I
TYPICAL GENERATORS CONSIDERED IN THE STUDY

COMPANY	TYPE	SIZE kW	FUEL TANK (GALLON)	RUN TIME (Rated)	GALL ON /kWh	\$/kWh (\$12/ GALLON)
ROBIN SUBARU	RGD3300	3	2.06	6	0.11	0.14
ROBIN SUBARU	RGD3300N	3.3	4.5	13.1	0.10	0.12
ROBIN SUBARU	RGV 4100	3.6	4.39	7	0.17	0.21
JOHNDEERE	G4400K	4	7	12.7	0.14	0.17
ROBIN SUBARU	RGD5000	4.5	4.23	8	0.12	0.14
HONDA	EB5000XK1	4.5	4.5	5.7	0.18	0.21
HONDA	EG5000XK1	4.5	1.9	2.4	0.18	0.21
ROBIN SUBARU	RGV6100	4.8	5.68	7	0.17	0.20
COLEMAN POWERMATE	Premium Plus 5000	5	5	5.5	0.18	0.22
JOHNDEERE	G5500K	5	7	9.5	0.15	0.18
JOHNDEERE	G5500KE	5	7	9.5	0.15	0.18
HONDA	EB6500SX	5.5	4.5	5.3	0.15	0.19
HONDA	ES6500K1	6	4.4	4.6	0.16	0.19
COLEMAN POWERMATE	Premium Plus 6500	6.5	5	4	0.19	0.23
HONDA	EB11000	9.5	6.9	4.4	0.17	0.20
COLEMAN POWERMATE	Industrial 10000	10	8	3.5	0.23	0.27
HONDA	EB12DAGC6	10	10	9	0.11	0.13
ROBIN SUBARU	RGV 12000	10	11.26	8	0.14	0.17
ROBIN SUBARU	RGV13000T	10	11.36	8.7	0.13	0.16
COLEMAN POWERMATE	Industrial 12000	12	8	3.5	0.19	0.23

The data shown in Table I was obtained from the websites of the respective companies [5], [6], [7], [8]. The data shown in the last column of Table I assumes gasoline price of \$ 1.2/gallon. One can see that the generator fuel cost range from \$0.12/gallon to \$0.27/gallon.

In most markets the price of electricity does not exceed these prices for significant periods of time. Let us consider one typical market—New York Independent System Operator (NYISO). The Independent System Operator (ISO) coordinates day-ahead schedules and performs real time balancing of load and generation, settles real time imbalances etc.

The market prices in this field are represented by the Locational Based Marginal Prices (LBMP). In the Day-Ahead Market (DAM), the LBMP is computed on the previous day based on generation and energy transaction bids that are offered in advance to the NYISO. These prices are determined on an hourly basis for each of the state's eleven zones and for the four neighboring areas. Typically more than 90 % of energy transactions processed by NYISO occur in the DAM. [3].

Figure 1 shows price duration curve for 2001 for the Long Island zone where the price excursions were highest. The curve displays the times when the LBMP was above \$120/MWhr. The time coordinate of any point on the price duration curve shows the number of hours during which the price is higher than the price coordinate. Hence this graph displays the probability of gaining a profit for a certain cost of domestic generation. For instance in zone Long Island of 2001, the total hours that the LBMP is greater than 200\$/MWhr is 25 hours.

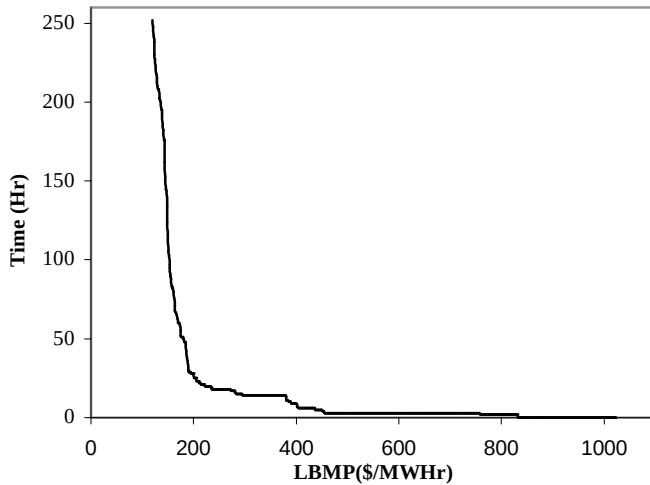


Figure 1. Price Duration Curve 2001 of Zone Long Island in DAM

If a supplier had a choice between purchasing energy from the spot market and purchasing it from a standby generator it would probably enter into an agreement to purchase from a generator at a price lower than the spot price. If the generator also collects revenues from capacity payments it might be called upon to provide energy during periods when the market price is lower than the generating cost.

Figure 2 shows the price duration curve for real time prices for the same zone (this has been truncated at \$200/MWhr). It is clear that even though the prices are higher than in the day ahead market and for a long period of time it is actually very volatile and it may not be feasible to start up a generator every time the real time price exceeds the generation cost because of the very brief duration of some of the price peaks. This is further explained as follows.

Comparing Figure 2 with Figure 1, it appears the price curve in real-time market is more attractive, for example, there are around 80 hours in RT whose LBMP is greater than \$300/MWhr as compared to only 14 hours in DAM.

TABLE II
POTENTIAL PROFIT FOR EACH TYPE OF GENERATOR IN 2001

GENERATOR TYPE	SIZE (kW)	Cost \$/kWh	Period of Operation (Hr)	Payment From Supplier (\$)	Cost For Each GEN. (\$)	Profit For each GEN. (\$)
RGD3300	3	0.14	182	105	75	30
RGD3300N	3.3	0.12	248	144	102	42
RGV 4100	3.6	0.21	22	32	17	16
G4400K	4	0.17	60	66	40	27
RGD5000	4.5	0.14	182	158	115	42
EB5000XK1	4.5	0.21	22	40	21	19
EG5000XK1	4.5	0.21	22	40	21	19
RGV6100	4.8	0.20	25	46	24	21
Premium Plus 5000	5	0.22	21	43	23	21
G5500K	5	0.18	50	74	44	30
G5500KE	5	0.18	50	74	44	30
EB6500SX	5.5	0.19	29	59	30	29
ES6500K1	6	0.19	29	64	33	31
Premium Plus 6500	6.5	0.23	20	55	30	25
EB11000	9.5	0.20	25	90	47	43
Industrial 10000	10	0.27	18	80	49	31
EB12DAGC6	10	0.13	208	388	277	110
RGV 12000	10	0.17	60	165	101	64
RGV13000T	10	0.16	80	200	125	75
Industrial 12000	12	0.23	20	102	55	47

Table III shows the high volatility of the real time LBMP. As we can see, the profitable price like \$121.96 may last only a minute, and then a little later the price may spiral down to as low as \$46.86. Although theoretically this price is very attractive in order to make a profit it is impracticable for a small generator to start-up as fast as that and only generate for that very short interval. This is may make it impractical in some cases for standby generators to participate in the real time market.

We should note that even though there is some potential for profit by participating in the day ahead market, these results are not universally applicable. They may occur in some highly dynamic markets such as California, and New York not in other stable markets. But even for this highly lucrative market like that of New York we can deduce from Table II, that the possible profit for the customer in the DAM is very limited. In this analysis we have not included the cost of the device offsetting some of the cost to some extent. It is an important fact to mention that zone Long Island has the highest price and maximum possible hours among the 15 zones in 2001. The program is only feasible for the regions that are characterized by a highly unstable market price. However, for some other zones, in where the LBMP is very low, this program is completely meaningless.

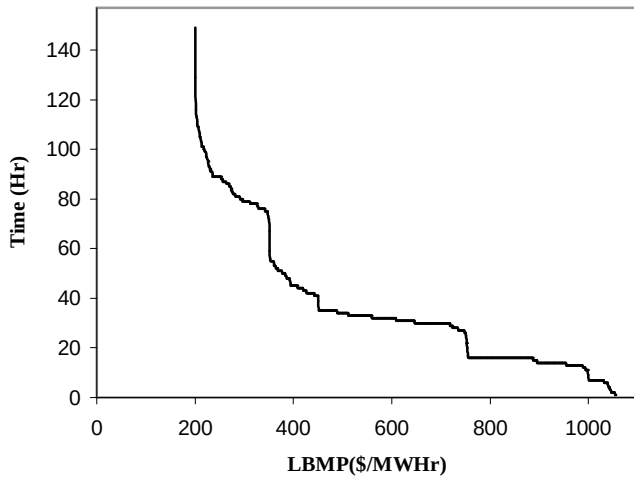


Figure 2. Price Duration Curve 2001 of Zone Long Island in RT Market

Other than the problems mentioned above we should realize that the price patterns reported here occurred in relatively immature markets. They may not necessarily repeat themselves again. Due to various companies entering this business the prices may considerably be stabilized rendering redundant the analysis provided above.

It is also to be noted that on account of a large factor of chance in utilizing this alternative the profits if ever obtained may still be very slim.

On basis of the above arguments we find that such a system may not be sufficiently feasible for all markets though applicable to a selected few. We propose an alternative system below, which we envisage that will be more universally applicable and yet promise a significant benefit for both the consumer as well as the supplier, which may be a utility or a generation company.

TABLE III
A SAMPLE OF SIX CONSECUTIVE REAL TIME PRICES IN LONG ISLAND ON JUNE 17, 2001

Time	10:00	10:03	10:06	10:11	10:12	10:17
LBMP \$/MWhr	157.65	49.6	42.3	121.96	47.84	46.86

B. Revenues from sale of capacity

Various regulations exist stipulating the minimum capacity that is required to be maintained by a provider of generation. Utility companies have various options in order to satisfy these regulations. Other than obviously paying the penalty they may choose as conventionally done today to install generators delivering the required capacity in order to meet the requirement. A number of concerns arise due to practical implementation of this option.

Firstly there are a number of regulations on equipment used by utility companies that raise the cost of generators by many fold. Environmental regulations, efficiency requirements etc. required by commercial generators increase their cost

considerably. Installation costs of large generators are at least \$400/kW-yr. These installation costs will ultimately be shifted to the consumer, decreasing the demand and causing the utility company lose out in the long run.

By observing some of the statistics provided above we find that the load changes very drastically with time and may not always necessitate the switching on of these large generators. Also doing so would decrease their efficiency and may cause other problems associated with their functionality. A quick glance at the price curve would also make it clear that these generators would be used for a very small percentage of time making their investment vastly unjustified.

Other than the general problems mentioned above there might be other problems associated with the use of these generators. The utility company may not have the necessary time scale in order to implement this proposal increasing the risk involved in the project. This will also significantly add an additional cost to the project.

One of the possible solutions to satisfy the capacity requirement may be to put to use some of the generators possessed by these consumers. A large number of them are severely underutilized just waiting for sporadic outages to occur. The possible lease of the generator to the utility company may significantly defray their high maintenance costs incurred by such a consumer, reaping benefits for both the consumer as well as the company.

If a generation provider does not have adequate capacity of its own it can do one of three things: (a) it can build addition generation at a cost of \$400/kW-yr or more; (b) it can pay a penalty typically in the order of \$170/kW-yr in the summer months and \$85/kW-yr during the winter months; or (c) it can enlist the capacity of standby generators for which the owners have already paid so even if the supplier were to pay the owner at \$85/kW-yr it is still saving money.

The third option is what makes the plan lucrative for customers with standby generators. For example a typical 10kW generator will cost the consumer around \$2000. If the company pays the consumer at the rate of \$850 per year the consumer gains a reasonable income from the generator¹. On the other hand the installation costs the company would have incurred for equivalent installed the generation would be at least \$4000 per year. This gives them a significant advantage of leasing the generator from the customer.

We should note that the proposal for the substitution of the standby generators for the capacity requirements are more universal as compared to those of substitution for power. Its profit also does not depend like the latter on chance making profits more reliable and practicable. Hence we can conclude that the substitution of these standby generators will results in benefits to both the customer as well as the company.

¹ Note that this is a slightly optimistic estimate. If an owner makes a standby generator available for capacity, then it is likely that the generator will be called upon to operate, probably at the owner's expense. In some instances, with larger standby generators, the supplier has been known to pay the fuel cost of such usage, but this will usually be governed by the applicable agreement.

VI. CONCLUSIONS

This paper proposes a strategy for including standby generators in the present power distribution system. These standby generators may be principally used to supplement the energy and capacity requirements of the grid. The plan is shown to be beneficial to owners of standby generators, as well as to suppliers, which may be utilities or generating companies. It has been shown that the potential for capacity payments is quite high, while that for energy payment is slim.

The challenges to the implementation of the plan have been outlined, and it has been argued that these can be overcome with different degrees of effort, which may be justifiable in view of the potential benefits. Already, several utilities are considering this possibility.

Some development has already occurred in the design of an appropriate device to be used for interconnecting small standby generators to the grid, and for allowing a system operator to remotely switch and monitor the participating generators, and to record their output. Further development is in progress. Further research on the proposed plan is also in progress. The outcome of all the research and development mentioned here will be published when completed.

It is anticipated that the strategy outlined in this paper will stimulate more interest in the large, untapped resource available in the form of standby generators.

VII. ACKNOWLEDGMENT

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IX. BIOGRAPHIES

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