Study Of Reduction Of Load Peak Curves Using Microturbines

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Abstract

The objective of this paper is to show with an economic study the economical benefits of using a distributed energy resource, such as microturbines, for load peak curves reduction. Three different approaches were considered to reduce the consumption of a University: one working only in the more expensive months and two almost the whole year. The results are expressed in €/kWh.

Key Words

Distributed Energy Resources DER, Load management, Electrical machines, Gas microturbines.

1. Introduction

The deregulation process is something that started a decade ago in developed countries by political and technological reasons. Unfortunately the experience has not been so successful as it was planed, due to a lot of problems appeared from 2000 up till now (California Energy Crisis in 2000, Blackouts in Europe, United States and Canada in 2003). After these experiences, regulators and system operators believe more and more that additional electricity resources -Distributed Energy Resources- should be procured using an integrated process that takes into account not only supply resources -Distributed Generation- but also some demand policies: for example efficiency gains in demand -in long term horizon- or price responsiveness -in short term horizon-. This supposes a new scenario where demand and supply compete on an equal foot in energy markets. For example, California Energy Commission will finance new energy efficiency programs to achieve a forecasted demand reduction of 6000 GWh in 2008 [1].

In our study we will center our attention in probably one of the most promising DER technology: microturbines.

During the last few years microturbines with a power range of 25 – 500 kW have been developed for small-scale power generation, particularly for distributed power generation.

The advantages of microturbines respect to other technologies are several, such as their simplicity, compactness, modularity and low emission levels, as well as their relative low investment and maintenance costs. Microturbines are a great solution for stand-by power, power quality and reliability, peak shaving, and an attractive power supply option whenever combined heat and power (CHP) generation can be exploited. In figure 1 can be seen the small size and compactness of a 60kw microturbine.

Figure 1. Capstone C60 microturbine with unifin heat exchanger

2. Microturbines overview

Microturbines operate on the same thermodynamic cycle as traditional gas turbines, the Brayton cycle. In this cycle, the atmospheric air is compressed by the compressor, preheated in a recuperator, heated in an exothermic reaction inside the combustor and then expanded by the turbine. The excess power produced by the turbine moves a power generator [2] [3]. The higher gas temperature the higher power generation. However, microturbine inlet temperatures are generally limited to 1000°C or below to enable the use of relatively inexpensive materials for turbine wheels, and pressure ratios at 3.5 to 4.0.

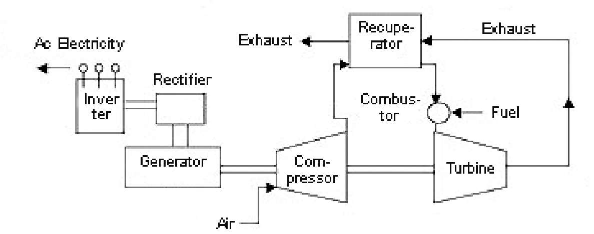


Figure 2. Brayton microturbine cycle

The Microturbine chosen for our study is the C60 model by *Capstone Turbine Corporation*. The manufacturer´s full load specifications at ISO conditions [4] for these machines are shown in the following chart.

Table I. Full load specifications for a C60 Capstone microturbine

Power	60 kW net (+0/-2)* 83 kVA max @ 480 V (stand alone) 60 kVA max (grid parellel)
Electrical Efficiency (LHV)	28% (±2)* * *Without gas compression option.*
Heat Rate (LHV)	12,900 kJ (12,200 Btu) / kWh
Exhaust Temp.	370°C (700°F) max
Exhaust Mass Flow	0.49 kg/s (1.06 lb/s)
Exhaust Energy	571,000 kJ/hr (541,000 Btu/hr)
NOx	<9 ppmV @ 15% O2 (<0.49 lb/MWh)
Fuel	Natural gas @ 75-80 psig HHV 849,000 kJ/hr (804,000 Btu/hr)

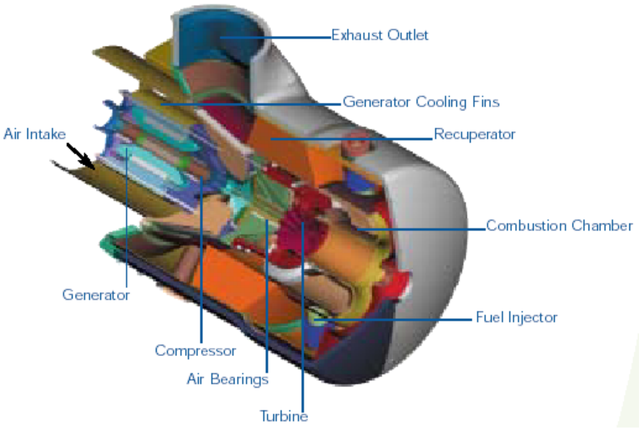


Figure 3. Section of a Microturbine (Capstone Source [4])

The generator has a two pole rotor and is mounted over the same turbine shaft. The cooling is accomplished by the turbine inlet air. No lubrication is needed as the air bearings operate free of contact which results in a better reliability and lower costs of manteinance. Compressor and Turbine are one stage and have centrifugal and radial flow respectively.

3. Case study

As we have stated in the introduction there are several problems in the network due to the deregulation process (lower investment in networks) and the growth of electrical consumption in the developed countries. One solution could be a reduction of the customer´s load, for instance by the use of more efficient equipments or load modification. That is one of the possible approaches, another is accomplished by small centers of power generation. The use of distributed energy resources acts as a possitive tool in the reduction of global network power transport and consumption and therefore in the customer load curve. In the paper we have chosen this option.

The customer chosen for the reduction was a University. The decision of this customer election for load management is justified in previous researches of the authors where the customers classified as Universities resulted as the best placed between lots of different kinds of customers after a classification accomplished by self-organizing maps (SOM) [5]. The load curve shapes can be seen in figure 4 for some characteristic months.

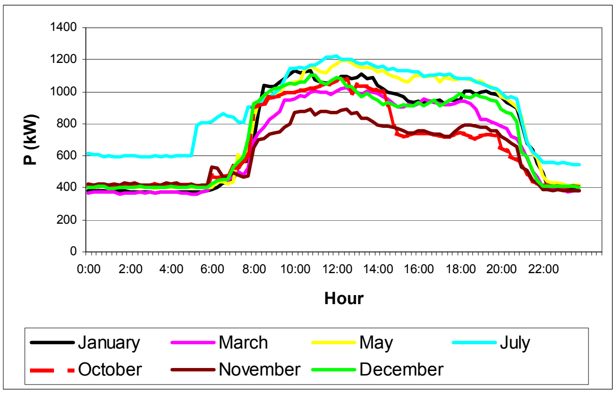
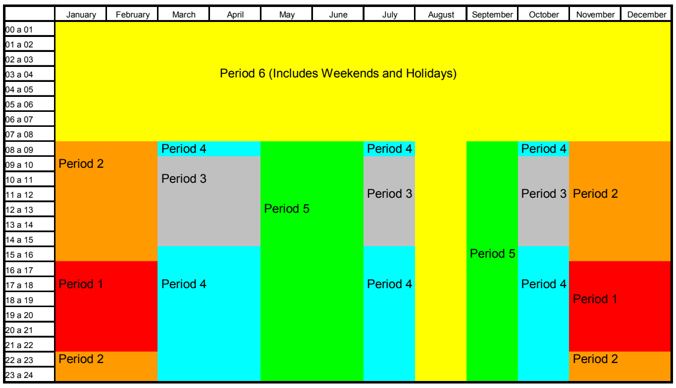


Figure 4. University´s load curves

The objective is to reduce the load curves to a flat 400kW level. Other reductions are possible but the solution adopted got smoother curves.



	January	February	March	April	May	June	July	August	September	October	November	December
00 a 01	Period 6 (Includes Weekends and Holidays)	Period 6 (Includes Weekends and Holidays)	Period 6 (Includes Weekends and Holidays)	Period 6 (Includes Weekends and Holidays)	Period 6 (Includes Weekends and Holidays)	Period 6 (Includes Weekends and Holidays)	Period 6 (Includes Weekends and Holidays)	Period 6 (Includes Weekends and Holidays)	Period 6 (Includes Weekends and Holidays)	Period 6 (Includes Weekends and Holidays)	Period 6 (Includes Weekends and Holidays)	Period 6 (Includes Weekends and Holidays)
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Figure 5. Six periods distribution

A. Electrical Network Cost

The University´s electrical tariff is based on a six periods time frame. This kind of tariff offers different prices depending on the daily hour and month. The different periods can be seen in figure 5. The final price for each period that is shown in Table II includes the network access, the energy price and all kind of taxes.

Table II. Electrical tariff in a final €/kWh value

Period	P1	P2	P3	P4	P5
€/kWh	0,14169	0,10571	0,10285	0,09531	0,08403

B. Reduction Strategies

Three different ways were considered in order to reduce the curves. All the solutions use 10 Capstone microturbines C60^{TM} by Gas Natural. Combined Heat and Power generation CHP wasn´t considered due to the lack of applications in the University that needed CHP. In the future a swimming pool and a sport´s training center will be built and CHP could be very interesting for the water heating.

The case A uses the microturbines only during the more expensive months (Period 1 and 2 of tariff) using three different load indices: 100%, 75% and 50%. The different efficiencies can be seen in table III. These indice are based in a C60 Test Report by US EPA [6].

Table III. Fuel consumption and power output per microturbine

Index (%)	Fuel consumption (KJ/h)	Power output (kW)	Efficiency (%)
100	849000	59.6	28,4
75	592730	44.5	27
50	446078	29.5	23,7

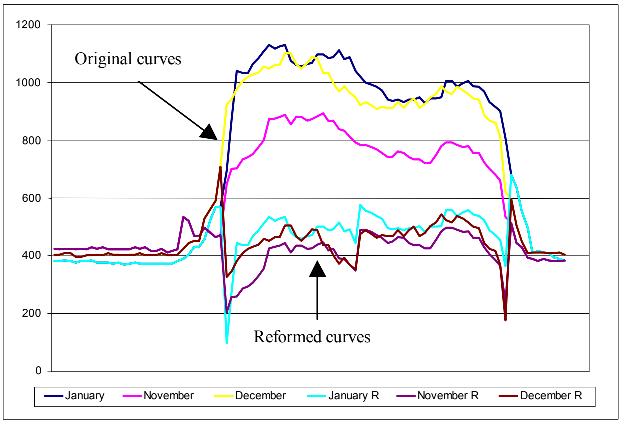

Figure 6. University´s load curves: original and reformed by case A

The cases B and C reduce the curves the whole year except August. The main difference between B and C is that in B the microturbines work in the same load levels of the case A while in C the different levels of load are achived using steps of 10, 8 or 5 microturbines at full load depending on the period.

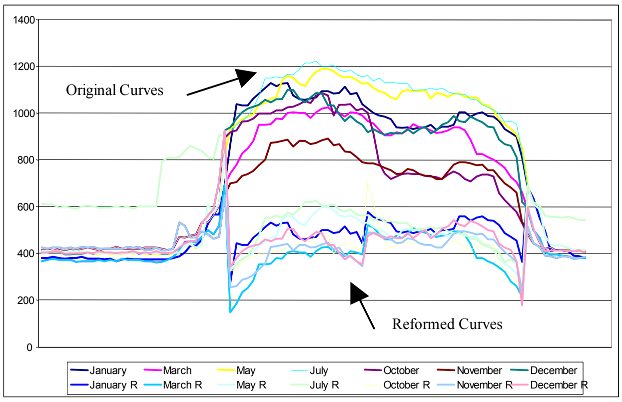

Figure 7. University´s load curves: original and reformed by case B

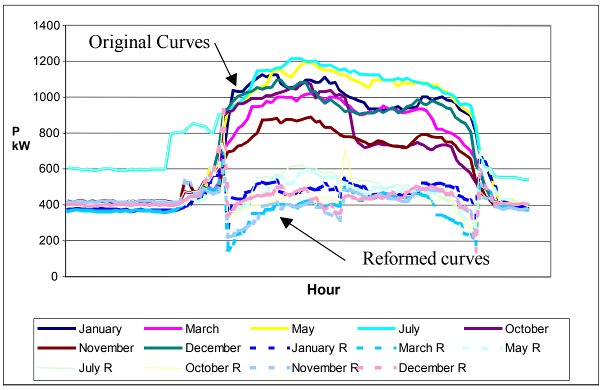

Figure 8. University´s load curves: Original and reformed by case C

The efficiencies for each load index and the output power are shown in table III and the different strategies can be seen in figure 7 and 8 over the six tariff periods schedule.

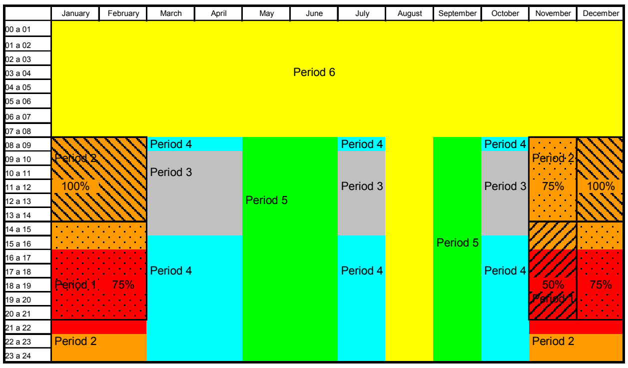

Figure 9. Strategy reduction A

Using the strategies we can get almost flat load curves in the months of operation, reducing electrical costs.

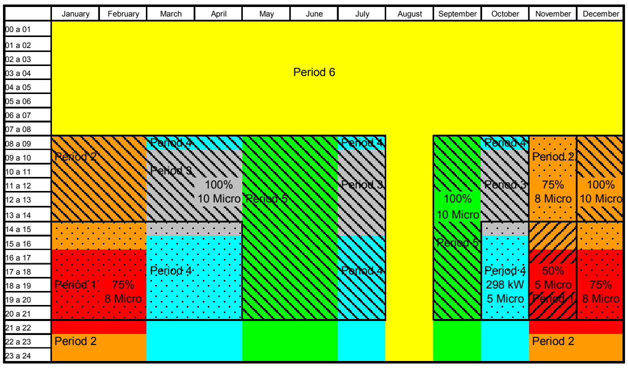

Figure 10. Strategy reduction B and C

C. Study of costs

To see if the installation is economically feasible three costs must be considered for the microturbine and compared to the network´s cost: Capital&Installation, Fuel and Operation&manteinance.

1) Capital&Installation cost (CTI)

The Capital and Installation costs represent the money needed to buy and to install the DER equipment in a determined place. The capital cost takes into account not only the direct costs but other indirect costs.

One of them is the oportunity cost. This one represents the benefit we would have obtained inverting the capital in another business. If the inversion in equipment and installation is paid by a bank loan the interest costs should be present in this cost too.

The value is shown in a €/kWh basis in the table V in order to be able to compare this cost with other kind of costs. It represents how much we must pay for each electrical kWh produced by the microturbine in its expected life. The expected life for these microturbines is 45000 hours which means the following ideal years of working.

Table IV. Microturbines life expectancy

Case	Ideal Life expectancy	Considered Life expectancy
A	46,78	30
B	16,03	16
C	18,13	18

As we can see in table IV the final expected life considered was a bit different. The case A changes a lot because a time over 30 years is too much time for a machine that working 24h/day would last only 5 years.

The fact that the case A uses the microturbines in a less intensive way makes that during the expected life of the microturbines fewer kWh were produced and that makes it the worst CTI value. The case C has the best €/kWh ratio due to a better efficiency during the years of service.

2) Fuel Cost (FC)

The fuel cost is clearly joined to the consumption of natural gas by the microturbines. The tariff has, as imagined, a great impact to the fuel cost ratio too.

The case A uses the microturbines only four months in a year, that makes this case to have not a great consumption for year. The more fuel is consumed in a year the better tariff it can be obtained. Of course the worst fuel cost ratio was the one for the case A due to the more expensive tariff of all of them. Case C uses the same tariff as case B, but the more efficient use of the microturbines allows it to have the lowest ratio value.

The expression of the FC in a €/kWh basis shows us how much in terms of energy costs worths to produce an electrical kWh.

3) Operation and Maintenance costs (O&M)

This cost represents variable and fixed costs. The fixed costs are related with the operation of the plant, for instance the wages of the workers. The variable costs include the costs of maintenance, such as filters changes, failures and reparation of some pieces, periodical inspections and so on. Microturbines have not expensive maintenance costs and that is the reason why we have considered them constant although they would have had a higher ratio in case A.

4) Network´s cost (CN)

The network´s cost is the price it should be paid for buying the kWh produced by the microturbines directly from the network. It takes into account the different periods of prices, figure 5 and table II

D. Costs Comparison

The total cost (CE) expressed in €/kWh is the price of a generated electrical kWh by the microturbine. It contains the CTI, FC and O&M costs. To be feasible our installation should have a cost per each electrical kWh produced lower than the price it should be paid for buying it from the network. So CTI must have a lower price than the total network´s price (CN).

The global results for each case can be seen in Table V.

Table V. Costs comparison

Case	CTI (€/kWh)	FC (€/kWh)	O&M (€/kWh)	**CE (€/kWh)**	**CN (€/kWh)**
A	0,08486	0,064140	0,004	0,1530	0,1175
B	0,04081	0,057322	0,004	0,1021	0,0999
C	0,03712	0,05506	0,004	0,0961	0,1000

As we can see only case C has a benefit. Case A is not feasible although it has the higher CN because the CTI is too expensive most of all because it does not use the whole expectancy life of the microturbines and has a worse gas natural tariff. Case B although has a lower CTI and a better FC ratio is not enougth for making it a feasible case. C is the best option without any doubt mainly for using the microturbines always at full load what results in the best efficiency of all the cases.

3. Conclusions

With our study we have shown that using a distributed generation source it can not only be improved the network working and the supply quality but reduced the electrical costs of a customer. Combined heat and power would have improved the efficiencies greatly [7] but although it has not been considered, the project is still feasible what states that this resources can be used this way too. However, each customer need to do an exhaustive study of the tariffs and load curves to assure the feasibility of the project. Microturbines perhaps are better placed as a distributed energy resource (DER) for small customers such as hotels, hospitals or supermarkets especially if CHP can be used.

4. References:

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