Business Opportunities and Dynamic Competition through Distributed Generation in Primary Electricity Distribution Networks

R. Raineri B., S. Ríos M. and R. Vásquez L.

Abstract—**We assess business opportunities to invest in Distributed Generation (DG) in a real electricity distribution network, through a simulation of a section of a real network of the Chilean electrical system consisting on 1,062 sections with conductors with 13 different sizes, and looking at the incentives of the incumbent distribution company and of new entrants. The technical and economic impact on losses, reliability and voltage in the area are verified. The solution analyzed determines a business opportunity for new investors where also final users are benefited. This work calls in the debate on the need to reformulate the current regulation model on electricity distribution defining clear rules to add Distributed Generation to enable any agent to develop the proposed business. The DG's success is based on the location of adequate sites to strategically establish few DG units being a substitute to network expansion.**

Index Terms—**Distributed Generation (DG), Business Opportunities, Reliability, Voltage Regulation, Investment Incentives.**

I. INTRODUCTION

Many countries have restructure and deregulate the electrical sector, where competition have leaded for an increasing interest to have cheaper, cleaner and more reliable electrical power systems. In this mode, the restructuring of the electrical industry is evolving in a trend to have a more responsive system, what can be achieved by the use of power sources of a reduced size. Here DG emerges as an alternative to be incorporated within primary distribution networks, to improve system reliability or as a substitute to enlarge conductors and substations capacity. Against the literature that advocates to restructuring of all the system (conductors, protections, the evaluation of wires and transformers [1], losses [2]-[3], reliability [4] and others factors) in this paper we strategically locate few DG units without network conditioning.

Economic regulation should consider the dynamic character of competition for the market what contrast with a standard static model of competition within the market [5], where today regulatory tools are generally based in static economic models being useless to regulate dynamic industries exposed to an increasing technological change [6]. In this sense, economic regulation that applies to the electric industry should be redefined to promote dynamic economic efficiency easing the process of innovation and adoption of new technologies that enhance society wellbeing.

The DG discussions about energy efficiency, reliability, economic profile, an environment and interconnection conflicts is growing [7]. This paper analyses the use of DG in response to higher power requirements in primary distribution networks analyzing it as a business opportunity for the incumbent electricity distribution company (DISCO) or a new entrant. This is considered within a segment of a real network operating in the Chilean electrical market, where the segment consists of 1,062 sections with conductors of 13 different calibers. On this system we evaluate technically and economically the effect of adding a 1.6 MW distributed generator bank, without modification of networks conductors where we use the unidirectional flows and protections of the actual network. The DG generator bank is integrated in the medium voltage segment, where we evaluate its implementation, the impact on loss reduction, sector reliability and voltage regulation. On this we use a technical and economic algorithm looking at a scenario where the use of DG takes to a technical improvement in the distribution sector analyzed, considering the economic incentives for the DISCO and a new entrant.

In our experiments cases even though the DISCO satisfy minimum service quality requirements, we find that DG units located in strategic places in the network can engender a business opportunity that is economically profitable for a new entrant investor, bringing at the same time a more reliable system to the consumers. In the case of the DISCO, DG units can become attractive as long as they turn into a good substitute for network expansions. Our results unveil the question of the actual non adoption of DG and the existence of barriers that prevent their addition due to the lack of clear rules and ways on how to repay for them, for the DISCO and new entrants. Further, in DISCO tariff setting process [8] the alternative to use DG is not considered. But, in a hypothetical case where DG ca be considered, its addition widens the menu of technologies availability for the regulator providing a substitute technology that can be well thought-out in the

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design of an efficient distribution company and its' cost structure.

II. DESCRIPTION OF THE SIMULATED DISTRIBUTION SYSTEM

The segment of the distribution network simulated corresponds to a radial configuration, with a high voltage substation that draws power from a 110 kV ring and distributes power to three feeders that we name α, β and γ, operating at 12 kV, and formed by 1,062 sections and 222 low-voltage transformers. The segment simulated of the actual distribution network is presented in Figure 1. In addition, Table I shows a summary of the sector analyzed by feeder, showing the lines' capacity, PEQ(MW) and QEQ(MVAr) that are defined in formulas (1) and (2), number of sections and low voltage transformers.

In our analysis we use as benchmark or "base case", a case where system load is given by the annual average load and losses of the system, where annual average active load and active losses is called PEQ and annual average reactive load and reactive losses is called QEQ are calculated by equations (1) and (2) respectively.

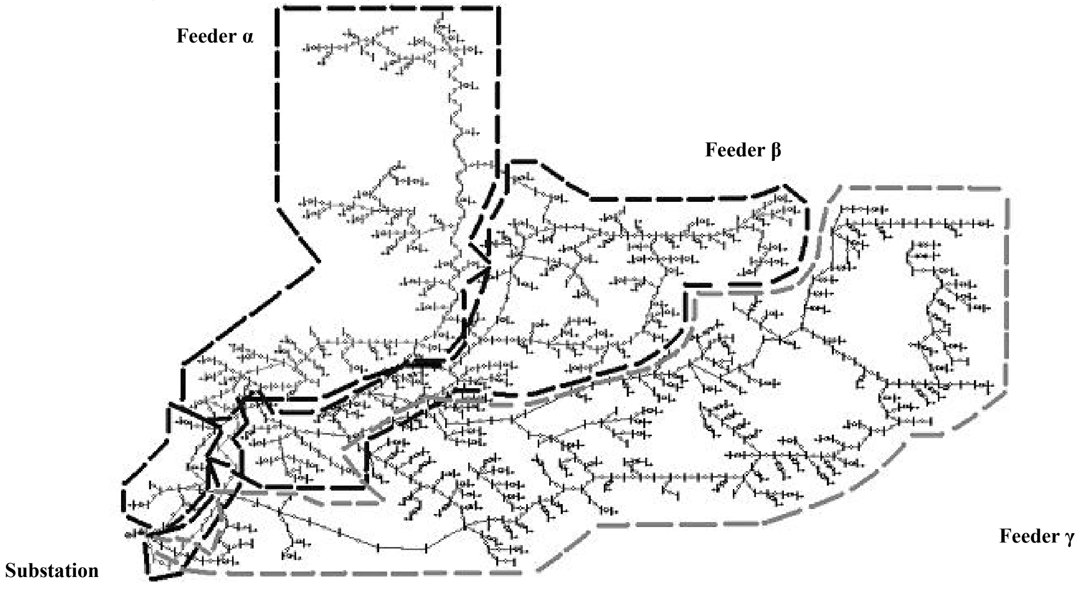


Figure 1. Simulated Distribution Area with Feeders α, β and γ

TABLE I

Simulated Sector Data Summary

	MW	MVAr	kVAr	Feeder							
	Peq	Qeq	Capacitors Banks	Sections	Overhead Lines	Underground lines	Number of Trunk sections	Number of lateral sections	Transformers	Loads	Maneuvers Equipment
Feeder α	6.45	1.46	0	243	233	10	169	74	48	48	24
Feeder β	6.40	2.79	600	366	361	5	293	73	70	70	57
Feeder γ	12.85	2.10	600	453	449	4	369	84	104	104	61
TOTAL	25.7	6.35	1200	1062	1043	19	831	231	222	222	142

$$PEQ^{\delta} = \frac{1}{8760} \cdot \sum_{i=1}^{8760} \left[\frac{1}{C^{\delta}} \sum_{k=1}^{C^{\delta}} \widehat{P}_{ik}{}^{\delta} + \frac{1}{S^{\delta}} \sum_{s=1}^{S^{\delta}} Pll_{is}{}^{\delta} + \frac{1}{T^{\delta}} \sum_{T=1}^{T^{\delta}} Plt_{it}{}^{\delta} \right] \qquad (1)$$

$$QEQ^{\delta} = \frac{1}{8760} \cdot \sum_{i=1}^{8760} \left[\frac{1}{C^{\delta}} \sum_{k=1}^{C^{\delta}} \widehat{Q}_{ik}{}^{\delta} + \frac{1}{S^{\delta}} \sum_{s=1}^{S^{\delta}} Qll_{is}{}^{\delta} + \frac{1}{T^{\delta}} \sum_{T=1}^{T^{\delta}} Qlt_{it}{}^{\delta} \right] \qquad (2)$$

Where;

δ = stands the index α,β or γ

C^{δ} = Is the number of load in the feeder δ

S^{δ} = Is the number of lines (sections) in the feeder δ

T^{δ} = Is the number of Transformers in the feeder δ

$\widehat{P}_{ik}{}^{\delta}, (\widehat{Q}_{ik}{}^{\delta})$ = Is the representative value, after of the application of coincidence factors in each hour of the year for all the active (reactive) loads of the feeder δ

$Pll_{is}{}^{\delta}, (Qll_{is}{}^{\delta})$ = Are the active (reactive) power losses in each sections of the feeder δ for each hours of the year

$Plt_{it}{}^{\delta}, (Qlt_{it}{}^{\delta})$ = Are the active (reactive) power losses in each transformers of the feeder δ for each hours of the year

$PEQ^{\delta}, (QEQ^{\delta})$ = Is the annual average active

In Figures 2 and 3, respectively, we show the band, within the maximum and the minimum in each hour in a day, a year round, for the hourly fluctuation, and also of the average in each hour in a day, a year round. This curves are a first approximation, due to that is a simplification of a problem more complex (separate the problem in summer curve, winter curve, weekend curve, daily work curve, consumer, industrial, commercial and residential, etc).[9]

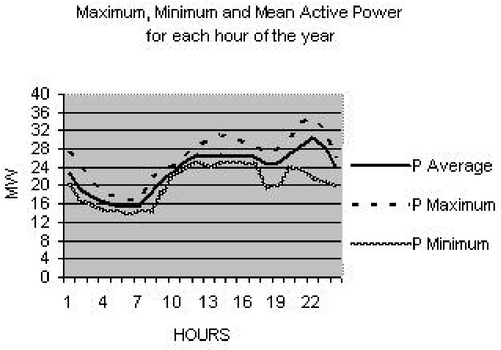


Fig. 2. Annual Active Load Curve

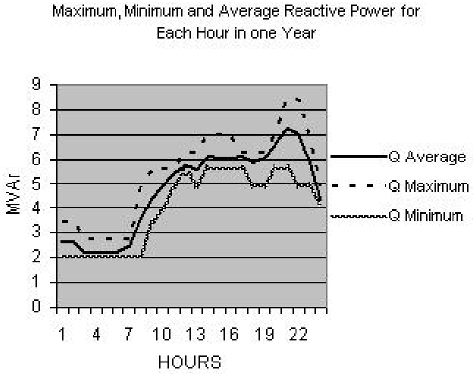


Figure 3. Annual Reactive Load Curve

III. Experiments performed

To evaluate the technical impact of DG we analyze four different scenarios including the “base case”, where by a simulation for each of them we examine the level of active power losses and reactive power losses, reliability [1] and voltage level. In the scenarios that we incorporate DG on the network we consider micro turbines with a modularity of 0.4 MW forming a distributed generator bank of 1.6 MW. This configuration leads to technical improvements. We are not necessarily looking for an optimal solution [10], an issue that goes beyond the objectives of this paper. The four cases analyzed are:

Base Case. Given by the performance of the segment of the distribution system under the technical parameters and the average annual load of the real segment in Figure 1.

Case I. With respect to base case, in this scenario we add the 1.6 MW distributed generator bank.

Case II. With respect to base case, in this scenario the load is increased in the distribution area in 20%, causing line saturation, event though the system stills fulfills minimum service quality requirements.

Case III, With respect to base case, in this scenario the load is increased in the distribution area in 20% and also we add the 1.6 MW distributed generator bank.

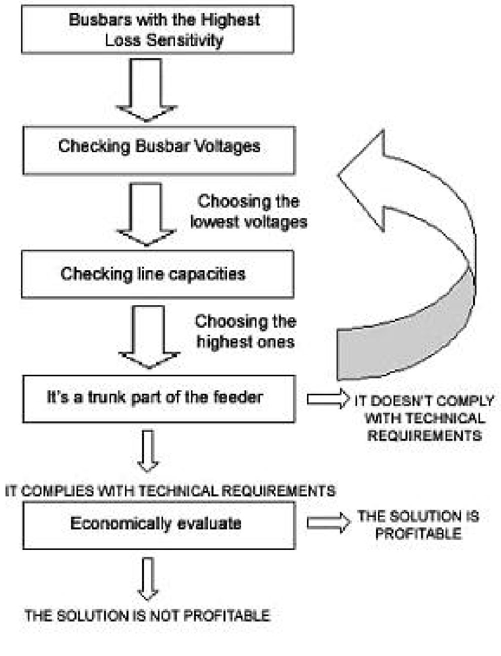
For each of the cases we perform an economic assessment looking at PEQ, QEQ, losses and reliability concepts, and the DG costs. In the next section we describe the algorithm used for the assessment of DG.

IV. DG Localization

To locate the DG in the network we look for a place where the units can produce an improvement both for the users and the new entrant investor. For these to happen, it’s necessary to bring about the following benefits: loss reduction, reliability improvement, voltage improvement and economically justified costs to implement DG.

Figure 4 describes the algorithm that we use to locate DG, where we pursue the following 5 steps:

a) determine the busbars with the highest sensitivity to losses;
b) check voltages in a) busbars choosing the ones with worst voltages;
c) on b) busbars select the lines with the highest capacity;
d) on c) lines check which of them are part of a main feeder;
e) on busbar of selected d) lines fit DG units and evaluate their technical and economic impact.



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[1] According do standard reliability indexes [10] that show number of interruption, frequency of interruption, etc.

Figure 4. DG Localization Algorithm

With this heuristic, we search a technically and economic better solution, where to find a profitable one we perform an economic evaluation that's described in Chapter IV. Technically we calculate the effect on loss power and loss reactive power by $\frac{\partial Plosses}{\partial Pi}$ and $\frac{\partial Qlosses}{\partial Qi}$, what reflects how losses change if more MW or MVAr are injected in busbar i. With that, we obtain the potential candidate busbars to locate DG.

For reliability purposes, it's important to note that candidate busbars must belong to the sector's trunk branches in order to prevent saturating secondary branches and not affecting local reliability.

This is based on the fact that some candidate busbars can be highly sensitive to the loss variation due to power injection; but the line capacity, together with the high circulating flow, is not able to support a DG.

To improve voltage, the effect of an additional injection of active and reactive power over a specific line or interface is evaluated. With that, the potential candidate busbars to locate DG are obtained.

The technical results for each of the cases studied are summarized in Table II below.

TABLE II
SUMMARY OF DATA FROM THE SIMULATED SECTOR

		P (MW)	Q (MVAr	3Ø Plosses (MW)	3Ø Qlosses (MVAr)	Saifi (inter/cust-yr)	Maifi (inter/cust-yr)	Saidi (hr/cust-yr)	Caidi (hr/cust-inter)	Asai	Asui	Ens (kWh/yr)	Avg. Ens (kWh/cust-yr)
BASE CASE	Feeder α	5.8	1.1	0.6525	0.363	0.587132	0.524218	2.332472	3.97265	0.999734	0.000266	17866.8	14.88897
	Feeder β	5.8	2.2	0.6025	0.594	0.727609	0.483378	2.013871	2.767792	0.99977	0.00023	10291.5	5.88086
	Feeder γ	11.6	1.5	1.215	0.6	1.098196	0.825997	3.57257	3.253127	0.999592	0.000408	26455.2	10.17506
CASE 1	Feeder α	5.67	0.9	0.6068	0.27	0.528155	0.443437	2.189404	3.660982	0.999757	0.000243	16677.2	13.89763866
	Feeder β	5.37	2.2	0.5140	0.594	0.637669	0.41884	1.863441	2.646731	0.99985	0.00015	9410.3	5.377316898
	Feeder γ	11.7	0.7	1.0692	0.14	1.021662	0.74383	3.424392	3.135706	0.999613	0.000387	25219	9.699599252
CASE 2	Feeder α	6.9	1.5	0.8483	0.45	0.623548	0.586712	2.439816	4.234518	0.999632	0.000368	18522.2	15.43513557
	Feeder β	7	2.6	0.7833	0.832	0.781412	0.523467	2.834981	2.834512	0.999668	0.000332	10934.5	6.24828875
	Feeder γ	14	2.1	1.4285	0.945	1.123657	0.883461	3.682748	3.334712	0.999395	0.000605	27498.7	10.57640549
CASE 3	Feeder α	6.8	1.2	0.7719	0.336	0.564571	0.505931	2.296748	3.92285	0.999688	0.000312	17132.6	14.2771379
	Feeder β	6.7	2.6	0.6896	0.832	0.691472	0.458929	1.984551	2.713451	0.999724	0.000276	9753.3	5.573316993
	Feeder γ	12.9	1.2	1.2285	0.312	1.047123	0.801294	3.53457	3.217291	0.999688	0.000511	25762.5	9.908637366

Saifi = System average interruption frequency index
Saidi = System average interruption duration index
Asai = Average service availability index
Ens = Energy not supplied
Maifi = Momentary average interruption frequency
Caidi = Customer average interruption duration index
Asui = Average service unavailability index
Avg. Ens = Average energy not supplied

A. Base Case

In Table II, feeder α has an equivalent load of 5.8 MW, feeder β supports an equivalent load of 5.8 MW and feeder γ has an equivalent load of 11.6 MW. Total reactive load is 4.8 MVAr, mainly formed by residential consumers and some important industrial consumers. Table II also shows the active 3Ø losses equivalent to 2.47 MW, resulting in a distribution losses percentage of 10.64%. Reactive 3Ø losses are 1.56 MVAr, with losses of 32.44%. As well, the reliability of the area analyzed is presented as measured through the typical system's indexes [11] for each feeder.

Table III shows that voltage regulation is keep above standard (0.93 p.u.). In fact, busbars that have the minimum voltage are around 0.95 p.u.

B. Case 1

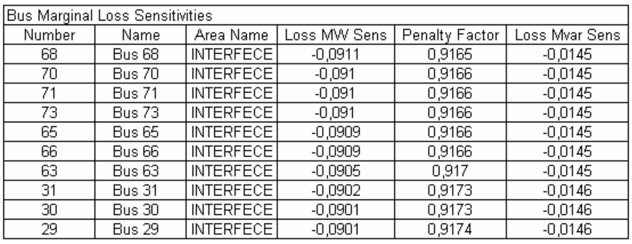
When adding a 1.6 MW generator bank, different effects are produced. Using the marginal losses sensitivity criteria, the potential candidates to locate the generator bank are found. Table IV shows the nodes that are most sensitive to the loss reduction in a descending order. Based on this sensitivity information, it would be expected that Busbar # 68 would be chosen. However, the selected busbar for the location of DG bank is Busbar # 29, and that is because it belongs to the trunk part of feeder γ, being able to support the DG bank without saturating the lines, nor damaging the reliability, and improving the voltage in the sector.

The 3Ø active losses are equivalent to 2.19 MW, resulting in a loss of 9.65% at distribution level. Reactive 3Ø losses are 1.01 MVAr, with losses of 26.42%.

TABLE III
MINIMUM VOLTAGE COMPARISON WITH AND WITHOUT DG

Number	Name	Area Name	DG	PU Volt
2	Bus 2	LOAD	Not	0.9514
1	Bus 1	INTERFACE	Not	0.9516
4	Bus 4	LOAD	Not	0.9517
686	Bus 686	LOAD	Yes	0.9618
684	Bus 684	LOAD	Yes	0.96184

TABLE IV
MARGINAL LOSSES SENSITIVITY FOR CASE I



Bus Marginal Loss Sensitivities

Number	Name	Area Name	Loss MW Sens	Penalty Factor	Loss Mvar Sens
68	Bus 68	INTERFECE	-0,0911	0,9165	-0,0145
70	Bus 70	INTERFECE	-0,091	0,9166	-0,0145
71	Bus 71	INTERFECE	-0,091	0,9166	-0,0145
73	Bus 73	INTERFECE	-0,091	0,9166	-0,0145
65	Bus 65	INTERFECE	-0,0909	0,9166	-0,0145
66	Bus 66	INTERFECE	-0,0909	0,9166	-0,0145
63	Bus 63	INTERFECE	-0,0905	0,917	-0,0145
31	Bus 31	INTERFECE	-0,0902	0,9173	-0,0146
30	Bus 30	INTERFECE	-0,0901	0,9173	-0,0146
29	Bus 29	INTERFECE	-0,0901	0,9174	-0,0146

In Table II we can compare the reliability of the sector with and without DG. With DG the system's indices improve, with a lower amount and duration of outages in the year due to this new source of generation.

After locating the DG bank, there is a redistribution of the busbars that have a minimum voltage and there is a voltage increase in the entire sector. In Table III we confirm that with no DG the minimum voltage busbars correspond to feeder γ, and after adding DG, voltage is increased in the entire sector and the minimum voltage busbars correspond to feeder α.

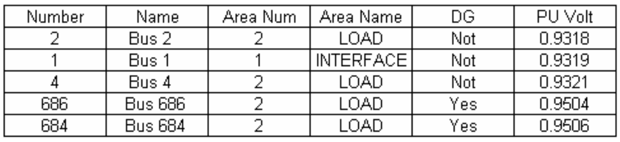
C. *Case 2*

In this case, the active 3Ø losses are equivalent to 3.06 MW, resulting in a loss of 10.87% at distribution level and reactive 3Ø losses are 2.23 MVAr, with a loss of 35.92%.

In Table II we show that the system's indexes worsen compared to base case because there are higher power requirements, with the effect of higher outage risks.

Table V illustrates that when we increase the load in 20%, the busbar voltages decrease, however, despite the increase in load, the minimum voltage busbars are above the standard (0.93 p.u.). As there is no DG and facing a load increase, the voltages in the busbars decrease an average of 0.02 p.u. compared to the base case busbars.

TABLE V
MINIMUM VOLTAGE COMPARISON WITH AND WITHOUT DG



Number	Name	Area Num	Area Name	DG	PU Volt
2	Bus 2	2	LOAD	Not	0.9318
1	Bus 1	1	INTERFACE	Not	0.9319
4	Bus 4	2	LOAD	Not	0.9321
686	Bus 686	2	LOAD	Yes	0.9504
684	Bus 684	2	LOAD	Yes	0.9506

D. *Case 3*

When we add a DG Bank, is expected to observe an improvement in the technical characteristics of the network. We locate a DG bank obtaining various direct effects: load redistribution, freeing up saturated lines; substantial voltage improvement in the entire sector; and an improvement in the system's reliability.

In this case, active 3Ø losses are equivalent to 2.69 MW, resulting in a distribution loss of 10.19%; and reactive 3Ø losses are 1.48 MVAr, with a loss of 29.6%.

Table II shows that reliability improves with DG because the system's indices show less and shorter outages.

Regarding voltage regulation, voltages increase and there is a redistribution of the busbars that have minimum voltages, as seen in Table V.

V. ECONOMIC ASSESSMENT

When analyzing the Chilean distribution system's costs, the distributor buys power at US$ 24.29 Mills/kWh, [12] (taking the average node price for the years 1998 to 2003) and adding the distribution companies markup, we have that the end user pays a price of US$ 90 Mills/kWh (july-2003)[13]. Thus, there is making up between of US$ 0 to 65 Mills/kWh, assumed to the Distribution Value Added (VAD) or distribution companies markup, which is calculated based on the distribution cost of an efficient distribution model company [8]. To determine the VAD, the model considers a 10% rate of return on investment. In this scenario, DG can be considered as another alternative to satisfy the demand of an increase in power requirements. However as it stands for today regulation, in Chile there are no rules and to enter the electricity market with a new investment in DG units, with its operating, maintenance and other costs.

A. *2003-2008 Demand Forecast*

A demand forecast was made for the analyzed sector in order to economically asses the DG bank and its technical characteristics through time. Figure 5 depicts the load curve projected for the years 2003 – 2008, for the base case and case 1. The load curve for cases 2 and 3, is 20% above load curve for base case and case 1.

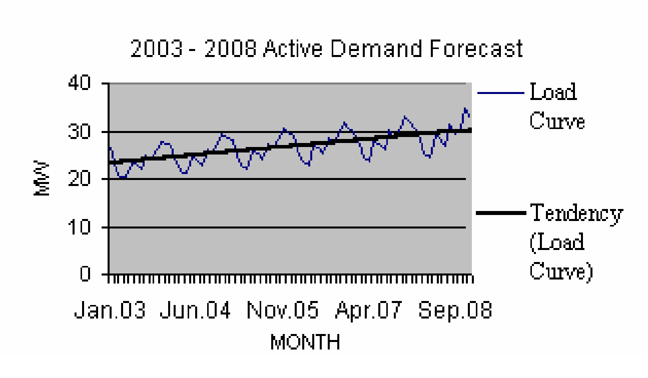


Figure 5. Active Demand Forecast for 2003-2008

B. *Investments Costs and O&M Costs for DG*

DG technology requires high investment costs and low operating and maintenance costs. Among DG technologies, the units that have the lowest costs are the micro-turbines. The investment cost for these units is 700 US$/kW [14], and if a heat recovery system is added, their investment cost increases to 900 US$/kW. With these, the investment for a 1.6 MW distributed bank is US$ 1,120,000 and with a heat recovery system increases to US$ 1,440,000. Regarding variable costs, fuel costs amount to US$ 15 Mills/kWh [15] and the operating and maintenance costs amount to US$ 5 Mills/kWh [14],[16].

C. DG Economic Assessment

The operating time of micro-turbines varies between 50,000-75,000 hours and within that period of time; maintenance time is expected in 5,000-8,000 hours [16]. Considering the setup, operating and maintenance costs, it's possible to calculate DG units' revenues and variable costs for power within a certain number of hours.

$$\text{Revenues}\ (US\$) = \frac{1}{1000} \cdot E \cdot N \cdot P_{Market} \quad (3)$$

$$VarCost\ (US\$) = \frac{1}{1000} \cdot E \cdot N \cdot \left(C_{Fuel} + C_{O\&M}\right) \quad (4)$$

For the distribution company, the cost of the energy bought that's displaced by the introduction of a DG unit is

$$Cost\ Energy\ Bought\ \ (US\$) = \frac{1}{1000} \cdot (E + Losses_E) \cdot N \cdot P_{Gen} \quad (5)$$

The parameters for formulas are: N as the generator's number of hours in use, E as the effective power generated in kW by the DG bank, P_{Market} as the market price faced in the analyzed market (US$ Mills/kWh), P_{Gen} as the generators price or buying price faced in the analyzed market by the distribution company (US$ 24.29 Mills/kWh), $Losses_E$ as the active losses that correspond to the effective power generated in kW, C_{Fuel} as the fuel cost of DG unit (US$ Mills/kWh), $C_{O\&M}$ as the operating and maintenance cost of the DG unit and 1/1000 is the US$ Mills conversion factor.

Let F(US$) be the capital investment annually that correspond to the annual flow of revenues required to recover the investment, defined as:

$$F(US\$) = \frac{I_o \cdot r}{1 - \dfrac{1}{(1+r)^t}} \quad (6)$$

Where I_0 is the initial investment, r is the discount rate, and t is the life time of DG units. We calculate a profitability index S to measure the profitability of DG units for a new investor:

$$S(\%) = \frac{\text{Revenues}\ (US\$) - \ VarCost\ (US\$) - F(US\$)}{F\ \ (US\$)} \quad (7)$$

In the case of the incumbent DISCO, it also has benefit due to the positive effect that DG units have over the overall energy losses of the network. To value in all the cases where a DG is install the DISCO benefit that it has in loss reduction, we use equation (8) based on the equivalent demand given by equations (1) and (2). Equation (8) calculates the variation of equivalent losses within a number of used hours in one year.

$$\Delta\ Losses \cdot (T - \delta) = \Delta \bar{E}_{Period} \quad (8)$$

Where, $\Delta Losses$ is the difference of the average values of the losses with and without DG in the simulated area, $\Delta\bar{E}_{Period}$ is the total value of the losses variation in one period, T is the time period analyzed and δ is the average maintenance time. To calculate the revenues from losses, it results in:

$$A(US\$) = \frac{1}{1000} \cdot M \cdot \Delta\, \bar{E}_{Period} \quad (9)$$

Where M is the power price (US$ Mills/kWh) and 1/1000 is the US$ Mills conversion factor.

A reliability index was used to economically assess the sector's reliability, based on the difference of the power that was not supplied to the three feeders within one year with and without DG. The equation we use is:

$$\Delta ENS = ENS^{withoutDG} - ENS^{with\ DG} \quad (10)$$

Where ENS is the power not supplied in kWh in the year, where the differences in reliability given by equation (10) is valued according to:

$$B(US\$) = \frac{1}{1000} \cdot R \cdot \Delta ENS \quad (11)$$

Where R is the unsupplied power price or system failure cost (US$ Mills/kWh) and 1/1000 is the Mills to US$ conversion factor.

To evaluate the economic effect of voltage regulation in the Chilean case, is necessary for the load in the analyzed sector to grow considerably and for the DISCO not to be able to deliver a voltage of 0.93 p.u. mandated by regulatory requirements, and since in our experiments the DISCO always deliver a voltage of 0.93 p.u. or above, this positive effect won't be considered in the economic assessment.

To analyze DG profits we consider two scenarios that could happen in the Chilean market, where we add the economic impact of the technical characteristics given in the different cases:

Scenario A, where P_{Market} is set to the actual price that the final consumer pays for the power, that is, US$ 90 Mills/kWh.

Scenario B, where P_{Market} is set to the lowest price of US$ 73 Mills/kWh[2], where the implementation of a 1.6 MW micro-turbine bank as an independent project becomes profitable for an external investor.

D. Economic Assessment for Cases under Scenario A

In this scenario, the calculation of DG profits and its analysis is based on 4 micro-turbines that add up 1.6 MW. Table VI depicts the revenues in the cases 1and 3, when the distributed bank sells power at 90 Mills/kWh.

TABLE VI
RESULTS UNDER SCENARIO A

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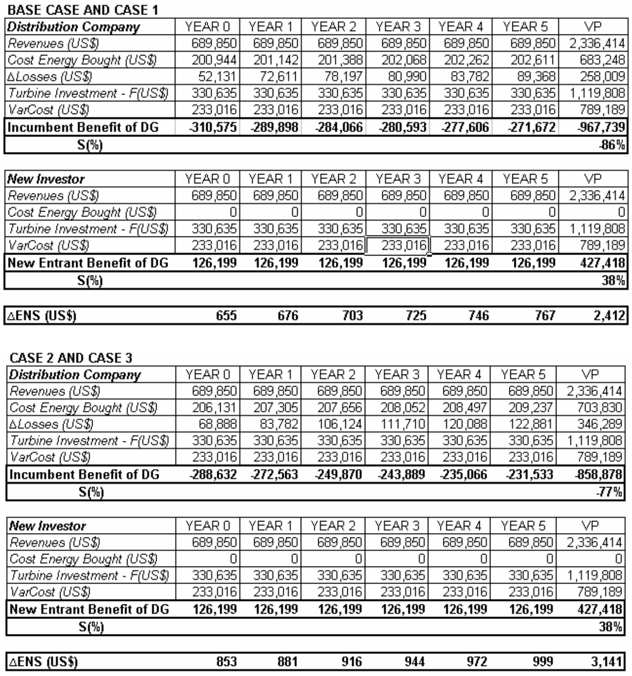
[2] Price without considering the reduction of losses and the reliability



BASE CASE AND CASE 1

Distribution Company	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	VP
Revenues (US$)	689,850	689,850	689,850	689,850	689,850	689,850	2,336,414
Cost Energy Bought (US$)	200,944	201,142	201,388	202,068	202,262	202,611	683,248
ΔLosses (US$)	52,131	72,611	78,197	80,990	83,782	89,368	258,009
Turbine Investment - F(US$)	330,635	330,635	330,635	330,635	330,635	330,635	1,119,808
VarCost (US$)	233,016	233,016	233,016	233,016	233,016	233,016	789,189
Incumbent Benefit of DG	**-310,575**	**-289,898**	**-284,066**	**-280,593**	**-277,606**	**-271,672**	**-967,739**
S(%)							**-86%**

New Investor	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	VP
Revenues (US$)	689,850	689,850	689,850	689,850	689,850	689,850	2,336,414
Cost Energy Bought (US$)	0	0	0	0	0	0	0
Turbine Investment - F(US$)	330,635	330,635	330,635	330,635	330,635	330,635	1,119,808
VarCost (US$)	233,016	233,016	233,016	233,016	233,016	233,016	789,189
New Entrant Benefit of DG	**126,199**	**126,199**	**126,199**	**126,199**	**126,199**	**126,199**	**427,418**
S(%)							**38%**

ΔENS (US$)	**655**	**676**	**703**	**725**	**746**	**767**	**2,412**

CASE 2 AND CASE 3

Distribution Company	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	VP
Revenues (US$)	689,850	689,850	689,850	689,850	689,850	689,850	2,336,414
Cost Energy Bought (US$)	206,131	207,305	207,656	208,052	208,497	209,237	703,830
ΔLosses (US$)	68,888	83,782	106,124	111,710	120,088	122,881	346,289
Turbine Investment - F(US$)	330,635	330,635	330,635	330,635	330,635	330,635	1,119,808
VarCost (US$)	233,016	233,016	233,016	233,016	233,016	233,016	789,189
Incumbent Benefit of DG	**-288,632**	**-272,563**	**-249,870**	**-243,889**	**-235,066**	**-231,533**	**-858,878**
S(%)							**-77%**

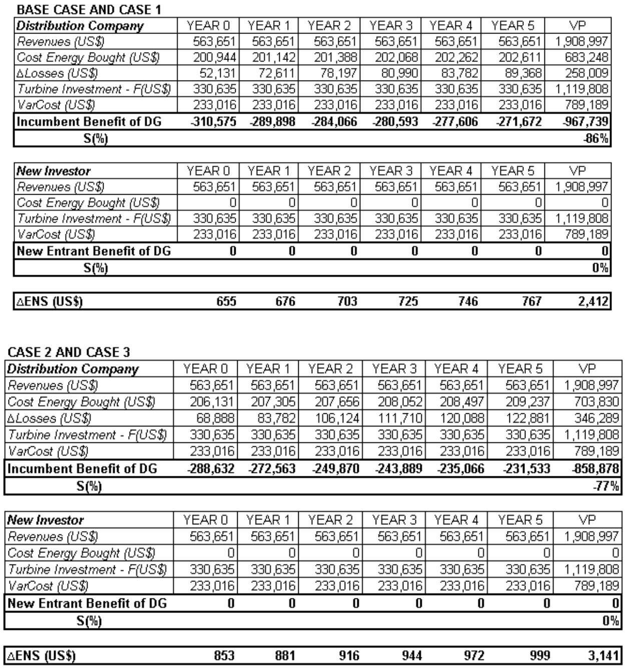
New Investor	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	VP
Revenues (US$)	689,850	689,850	689,850	689,850	689,850	689,850	2,336,414
Cost Energy Bought (US$)	0	0	0	0	0	0	0
Turbine Investment - F(US$)	330,635	330,635	330,635	330,635	330,635	330,635	1,119,808
VarCost (US$)	233,016	233,016	233,016	233,016	233,016	233,016	789,189
New Entrant Benefit of DG	**126,199**	**126,199**	**126,199**	**126,199**	**126,199**	**126,199**	**427,418**
S(%)							**38%**

ΔENS (US$)	**853**	**881**	**916**	**944**	**972**	**999**	**3,141**

E. Economic Assessment for Cases under Scenario B

In this scenario, the calculation of DG profits and their analysis is based on 4 micro-turbines that add up 1.6 MW. Table VII depicts the revenues in the cases 1 and 3, when the distributed bank sells power at US$ 73 Mills/kWh. This case denotes the inflection point that indicates that above these price conditions, is recommendable for an external investor to implement the proposed DG technology as long as no auditioned network interconnection changes apply (also without considering the incumbent DISCO benefits in the reduction of losses and the increase in reliability).

TABLE VII
RESULTS UNDER SCENARIO B



BASE CASE AND CASE 1

Distribution Company	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	VP
Revenues (US$)	563,651	563,651	563,651	563,651	563,651	563,651	1,908,997
Cost Energy Bought (US$)	200,944	201,142	201,388	202,068	202,262	202,611	683,248
ΔLosses (US$)	52,131	72,611	78,197	80,990	83,782	89,368	258,009
Turbine Investment - F(US$)	330,635	330,635	330,635	330,635	330,635	330,635	1,119,808
VarCost (US$)	233,016	233,016	233,016	233,016	233,016	233,016	789,189
Incumbent Benefit of DG	**-310,575**	**-289,898**	**-284,066**	**-280,593**	**-277,606**	**-271,672**	**-967,739**
S(%)							**-86%**

New Investor	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	VP
Revenues (US$)	563,651	563,651	563,651	563,651	563,651	563,651	1,908,997
Cost Energy Bought (US$)	0	0	0	0	0	0	0
Turbine Investment - F(US$)	330,635	330,635	330,635	330,635	330,635	330,635	1,119,808
VarCost (US$)	233,016	233,016	233,016	233,016	233,016	233,016	789,189
New Entrant Benefit of DG	**0**	**0**	**0**	**0**	**0**	**0**	**0**
S(%)							**0%**

ΔENS (US$)	**655**	**676**	**703**	**725**	**746**	**767**	**2,412**

CASE 2 AND CASE 3

Distribution Company	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	VP
Revenues (US$)	563,651	563,651	563,651	563,651	563,651	563,651	1,908,997
Cost Energy Bought (US$)	206,131	207,305	207,656	208,052	208,497	209,237	703,830
ΔLosses (US$)	68,888	83,782	106,124	111,710	120,088	122,881	346,289
Turbine Investment - F(US$)	330,635	330,635	330,635	330,635	330,635	330,635	1,119,808
VarCost (US$)	233,016	233,016	233,016	233,016	233,016	233,016	789,189
Incumbent Benefit of DG	**-288,632**	**-272,563**	**-249,870**	**-243,889**	**-235,066**	**-231,533**	**-858,878**
S(%)							**-77%**

New Investor	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	VP
Revenues (US$)	563,651	563,651	563,651	563,651	563,651	563,651	1,908,997
Cost Energy Bought (US$)	0	0	0	0	0	0	0
Turbine Investment - F(US$)	330,635	330,635	330,635	330,635	330,635	330,635	1,119,808
VarCost (US$)	233,016	233,016	233,016	233,016	233,016	233,016	789,189
New Entrant Benefit of DG	**0**	**0**	**0**	**0**	**0**	**0**	**0**
S(%)							**0%**

ΔENS (US$)	**853**	**881**	**916**	**944**	**972**	**999**	**3,141**

VI. CONCLUSIONS

The heuristics work well when some DG units are located in strategic places. As the power growth is not in accordance with the network restructuring, few DG units can be useful to improve system reliability, and eventually to postpone the conductors' expansion.

Due to the lack of regulation to add DG technologies, some agents see DG as a threat and since the pricing of electricity distribution network is based in a distribution added value concept, which looks at network investments; there are no clear rules on how DG units can participate in the calculation. In addition, there are entry barriers for third parties to enter with DG in the network, for example, lack of definition in the DG units' interconnection charges or wheeling for the use of distribution networks, etc.

DG is an alternative that can be potentially implemented in the Chilean market since it has been proven that there are profitable opportunities for DG units in the Chilean market distribution area. Even more, for the case of the distributed bank analyzed, there is a solution that benefits both the customers and also the investor that implements the technology.

A distributor company that has rights over the networks has the advantage of being the first to enter the market with DG technology, being able to sell power at the same price and benefiting from the loss reduction, where reliability improvement and voltage increases in the sector benefit the consumers with a better-quality power delivery. In the analyzed cases the incumbent should decide to replace the cost base of an ongoing business where it has large sunk investments. Since the incumbent cannot benefit from reliability improvements, because it already satisfies minimum quality standard requirements, it finds DG investment unprofitable. On the other hand, a new entrant faces a business opportunity where it can dispute incumbent revenues at the cost of DG investment and operating and maintenance costs.

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