Analysis of the Connection of a Microturbine to a Low Voltage Grid

António Amorim, *EDP*, José Oyarzabal, *LABEIN*, and Nuno Melo, *EDP*

***Abstract* — Expected advantages to Customers, to utility and to environment, from the connection of a microturbine to a low voltage grid, are presented. The main components and loads of the designed microgrid are characterised, and some performance results that shall be achieved on the system are presented.**

***Index Terms* — Cogeneration; Dispersed Generation; Losses; Power Demand; Power Distribution; Power Distribution Reliability; Tubines.**

I. Introduction

This document presents a brief characterisation of a Portuguese Low Voltage (LV) grid, which integrates a micro-cogeneration system, supported by a microturbine. After the implementation of this microturbine, with dual-mode capability, some field tests have been done to analyse the behaviour and the performance of the system in the transition between islanded and grid connected modes. The document focuses some improvements in terms of efficiency and supplying reliability that can be achieved with the supplying of some LV Customers through this microturbine.

II. Global Framework

This project is being developed in Frielas, a small village in the suburbs of Lisbon. This residential zone is supplied by a LV feeder from a public distribution power station (PTD 0292) of 200kVA, which transforms power from 10kV to 400V.

Recently, it was installed a micro-cogeneration system, based in a microturbine Bowman of 80kW, which generates heat and power to a Natural Gas (NG) station and exports the remaining power to the Medium Voltage (MV) network, by another MV/LV public distribution power station (PTD 1063). The microturbine is the single micro-source integrated in this distribution power system.

In near future, with some reconfigurations in the grid, the microturbine shall supply the nearest section of the LV feeder (fifteen Customers actually supplied by power station PTD 0292), as showed in the Fig. 1.

III. Topology of the Microgrid

The schema of the Fig. 1 shows the microturbine connected to the section of LV feeder supplying the fifteen Customers, and connected to the power station PTD 1063 for injection of remaining power in the MV network. This micro-source only has potential capacity to supply, in islanded mode, the following fifteen Customers.

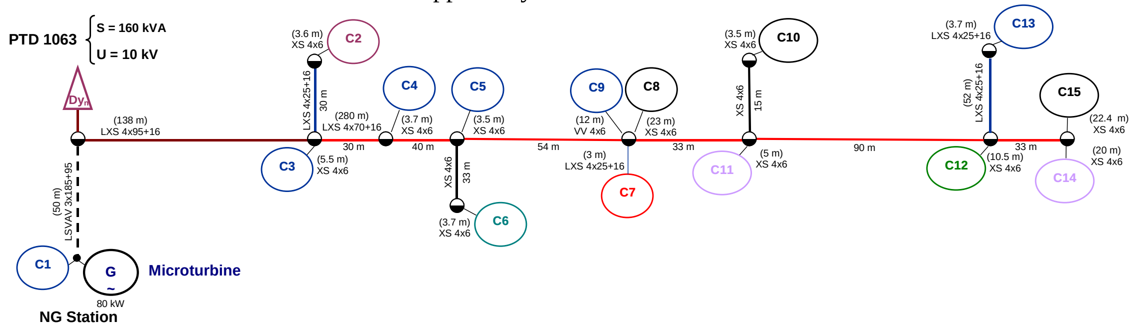

Fig. 1. Schema of the microgrid after reconfigurations of the actual LV feeder (Cn – Customer n; G – Microturbine; PTD – MV/LV Power station)

A. *General Characterisation of the Power Station PTD 1063*

The main electrical characteristics of the power station PTD 1063 that shall connect the microturbine and the Customers to the MV network are described below:

1) Rated power: 160kVA;
2) Nominal primary voltage: 10kV;
3) Nominal secondary voltage: 400V;
4) Leakage impedance: 4%;
5) Number of taps: 5;
6) Tapping range: ±5%;
7) Short circuit power at the LV bus: 3120kVA;
8) Earthing system: Dyn.

The Fig. 2 shows this power station, used by now only to export the generated power from the microturbine to the MV network. This power station shall be used to export the exceeding power and to supply the microgrid when the microturbine is out of order.

Fig. 2. Overhead MV/LV public distribution power station PTD 1063

Fig. 3. Microturbine Bowman installed in the NG Station

B. General Characterisation of the Microturbine

The microturbine Bowman (Fig. 3) installed in the NG station is supplied by natural gas and provides heat to these industrial facilities. This micro-cogeneration system has the following main characteristics:

1) Manufacturer: Bowman Power;
2) Model: Turbogen TG80RC-G;
3) Electrical Output Power: 80kVA (Max. active power: 80kW);
4) Thermal Output Power: 136kW;
5) Output Voltage: 380-480V, 3 phase, 4 wire, 50/60Hz;
6) Estimated Annual Availability: 85%.

The electric generator runs at the turbine speed on a single shaft. This is a permanent magnet electric machine of two poles, which can run as generator (3-phase output voltage with variable amplitude and frequency) or as motor with variable speed.

For the connection of this micro-source to the LV grid it is used an AC/DC – DC/AC power electronic module, which consists on two 3-phase power bridges controlled by PWM at 15kHz. The input and output frequencies of this power electronic module can vary respectively between 0 – 1.6kHz and 50 – 60Hz.

The following values show the performance of the microturbine, in normal operation conditions, during the initial operating months.

1) Electrical efficiency: 26.2%;
2) Thermal efficiency: 58.5%;
3) Global efficiency: 84.7%;
4) Water temperature: from 40 ºC up to 60 ºC.

C. General Characterisation of the Microgrid's Loads

In order to perform a brief characterisation of the loads, the next table presents some data about the Customers' facilities, focusing on the activity, contracted power, phase system (three phase or mono phase) and main loads.

TABLE I
CHARACTERISATION OF MAIN LOADS TO INTEGRATE IN THE MICROGRID

Ref.	Customer Activity	Power (kVA)	Phase System	Main Loads of the Customers
C1	Industrial (NG Station)	20.7	3 ph	PLC; Boilers; Compressor
C2	Agricultural	10.35	3 ph	Water Pump; Lighting
C3	Commercial	20.7	3 ph	Warehouse to Rent
C4	Commercial	20.7	3 ph	Warehouse to Rent
C5	Commercial	20.7	3 ph	Warehouse to Rent
C6	Industrial	13.8	3 ph	Welding; Turning-Lathe
C7	Industrial	41.4	3 ph	Refrigerators; Lighting
C8	Agricultural	6.9	1 ph	Water Pump; Lighting
C9	Commercial	20.7	3 ph	Lighting; HVAC
C10	Agricultural	6.9	3 ph	Water Pump; Lighting
C11	Residential	3.45	1 ph	Lighting; Water Pump
C12	Industrial	17.25	3 ph	Water Pump and Treatment
C13	Industrial	20.7	3 ph	Lighting; Machinery
C14	Residential	3.45	3 ph	Lighting; HVAC
C15	Residential	6.9	3 ph	Lighting; HVAC

Based on data of the last year, 2004, the following table presents the Customer annual average demand and the required energy, generated in a centralized power plant, to supply each Customer. The losses presented in the table include all technical energy losses in the Transmission and Distribution (T&D) systems, from the power plant to the local of consumption, including the transmission in very high voltage and the distribution from high voltage to low voltage.

TABLE II
CHARACTERISATION OF DEMAND, CENTRALIZED GENERATION AND LOSSES FOR SUPPLYING THE CUSTOMERS

Ref.	Power (kVA)	Phase System	Average Yearly Local Demand (kWh)	Average Yearly Centralized Generation (kWh)	Average Yearly T&D Losses (kWh)
C1	20.7	3 ph	36472	40079	3607
C2	10.35	3 ph	1658	1822	164
C3	20.7	3 ph	3000	3297	297
C4	20.7	3 ph	3000	3297	297
C5	20.7	3 ph	3000	3297	297
C6	13.8	3 ph	449	493	44
C7	41.4	3 ph	146742	161255	14513
C8	6.9	1 ph	1419	1559	140
C9	20.7	3 ph	2616	2875	259
C10	6.9	3 ph	280	308	28
C11	3.45	1 ph	3160	3473	313
C12	17.25	3 ph	6974	7664	690
C13	20.7	3 ph	6392	7024	632
C14	3.45	3 ph	1268	1393	125
C15	6.9	3 ph	503	553	50
Total			**216933**	**238388**	**21455**

All loads (Customers) have an average yearly demand of 217MWh. To supply these Customers by a typical T&D system, with centralized generation, it is required to generate about 238MWh, being the power losses about 21MWh.

IV. EXPECTED ADVANTAGES OF THE MICROGRID

Based on the same data of 2004, the following table presents an analysis of the two alternative scenarios – "Customers supplied by typical distribution system" and "Customers supplied in microgrid". It is assumed that during the year 2004 occurred two MV interruptions and one LV interruption in the distribution system that supplies the Customers.

TABLE III
ANALYSIS OF THE TWO SCENARIOS OF SUPPLYING THE CUSTOMERS TYPICAL DISTRIBUTION GRID OR BY MICROGRID

	Customers Supplied by Typical Distribution System	Customers Supplied by Microgrid
Yearly Number of Voltage Interruptions	3	1
Yearly Interruption Time (min)	153	60
Yearly ENS (kWh)	33	13
Yearly ENS by LV Maintenance (kWh)	1.3	1.3
Yearly Energy Generation (kWh)	238388	219554
Yearly Losses (kWh)	21455	5446

ENS – Energy Not Served

The yearly losses in the scenario of "Customers supplied by typical distribution system" (21MWh) include the losses in the full LV grid (5.7MWh) and the losses in the T&D systems (15.7MWh), from the centralized power plant. In a microgrid scenario, the yearly losses are only related with the reconfigured LV feeder, from the microturbine (located in NG station) to the local of consumption (Customers facilities).

In this analysis it is assumed that microturbine is always available to supply the loads when occur a MV interruption. For this reason, in a microgrid scenario, the LV Customers are not disturbed by MV interruptions.

With integration of the microturbine in this microgrid, it is expected the following potential improvements:

1) Reduction of the number of voltage interruptions from 3 to 1 interruption per year – Improvement of 66,6%;
2) Reduction of the interruption time from 153 minutes to 60 minutes per year – Improvement of 61%;
3) Reduction of the ENS from 33kWh to 13kWh per year – Improvement of 61%;
4) Reduction of the losses from 21MWh to 5.4MWh, due to no utilization of the T&D networks to supply the customers and as consequence of the reduction of the losses in the LV feeder – Improvement of 74%.

In a global perspective, the implementation of this real LV microgrid shall save about 16MWh (about 1400€, considering an average price of 0.0887€ per kWh), per year, to supply 217MWh to these fifteen Customers. On the other hand, the system reliability shall be significantly improved as well as the overall quality of service.

V. CONCLUSION

In fact, the implementation of micro-cogeneration systems in LV grids shall improve not only the overall efficiency of the electric systems but also the supplying reliability. The operation guarantee of some LV feeders, even with MV interruptions, is an advantage to Customers, to utilities and to environment. The activities of the Customers are not disturbed and the utilities shall reduce the ENS.

However, the results of this study cannot be generalised to other LV grids. In this particular study case, the LV feeder was reconfigured according to the microturbine capacity and the financial expenditures were disregarded.

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VII. BIOGRAPHIES

António Amorim received his Degree in Electrical Engineering - Automation, Energy and Electronic and his M.Sc. Degree in Systems and Automation by University of Coimbra, Portugal, in 1992 and 1999 respectively. He has been involved in the planning of distribution networks, in network optimisation studies and in the economic evaluation of distribution network projects. Presently he is head of the Technological Innovation Department of EDP Distribuição Energia.

Nuno Melo received his Degree in Electrical Engineering - Automation, Energy and Electronic and his Postgraduation in Energy by University of Coimbra, Portugal, in 1999 and 2002 respectively. Presently he is a M.Sc. student of Electrical and Computers Engineering from the University of Coimbra. He is involved in technological innovation activities and power quality studies in EDP Distribuição Energia.