Fixed Energy Systems for Aircraft at Zurich Airport

Content

Imprint

Published by:	Unique (Flughafen Zürich AG), P.O. Box, CH-8058 Zurich, www.unique.ch Environmental Services and Technical Facility Management [environment@unique.ch]
Date:	March 2009
Status:	Final / 2009-03_ZRH_Aircraft-FES.doc
Key Words:	APU – Aircraft – Airport – Fixed Energy Systems – Zurich

1 Introduction

Aircraft during ground times at airports require electrical energy (115 volts at 400 Hz) and depending on the ambient conditions also pre-conditioned air (PCA) for heating or cooling of the cabin. Such energy can either be provided by the aircraft built-in APU (Auxiliary Power Unit) or typically by ground support equipment (GPU - Ground Power Unit, ACU - Air Climate Unit, mobile heating unit). In addition, fixed energy systems are installed and operated by the airport or its tenants (table 1).

Table 1: Ways of providing energy to the aircraft during ground times

Energy Systems for Aircraft			
	Aircraft built-in APU	Mobile Units	Fixed Energy Systems
			
Electricity (400Hz)	✓	✓	✓
PCA (air)	✓	(✓ - ACU)	✓
MES (main engine start)	✓	(✓ - ASU)	---

Operation of aircraft APU with its low efficiency rate of 8-14% is subject to gaseous emissions and noise, thus often contributing significantly to the local air quality impacts and site noise impacts. To mitigate emissions and noise, fixed energy systems can be designed that provide electrical energy and pre-conditioned air to aircraft as depicted in figure 1.

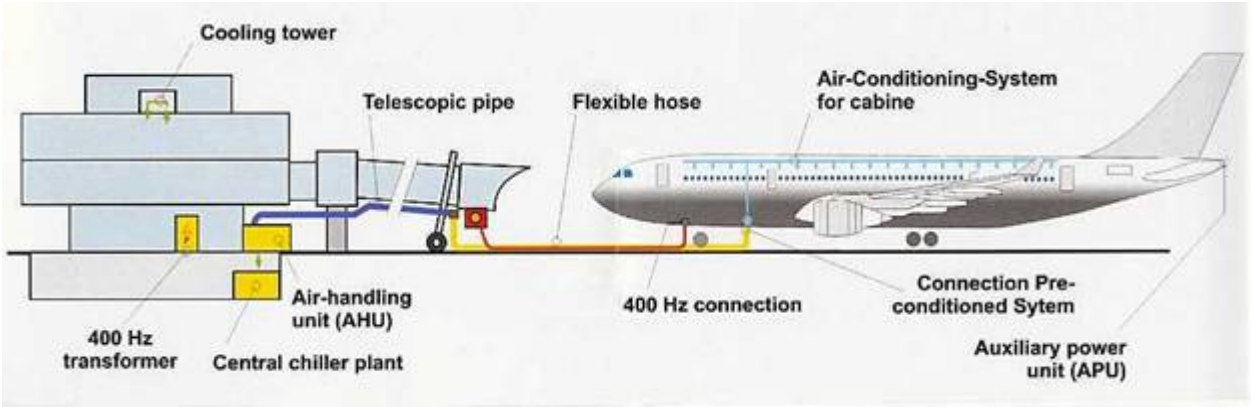


Figure 1: Basic layout of fixed energy systems

2 Zurich Airport Situation

Given the stringent environmental legislation in Switzerland and the ambient air quality conditions in the area where Zurich airport is located, the airport authority has started as early as 1990 to design and implement air quality mitigation plans. Part of such mitigation plans have always been all activities associated with the handling of the aircraft. This also includes the ground power delivery to aircraft during their ground time. To this end, Zurich airport provides both stationary 400 Hz and PCA at all hard stands and mandates the airlines to use the systems.

The general airport layout is depicted in figure 2.

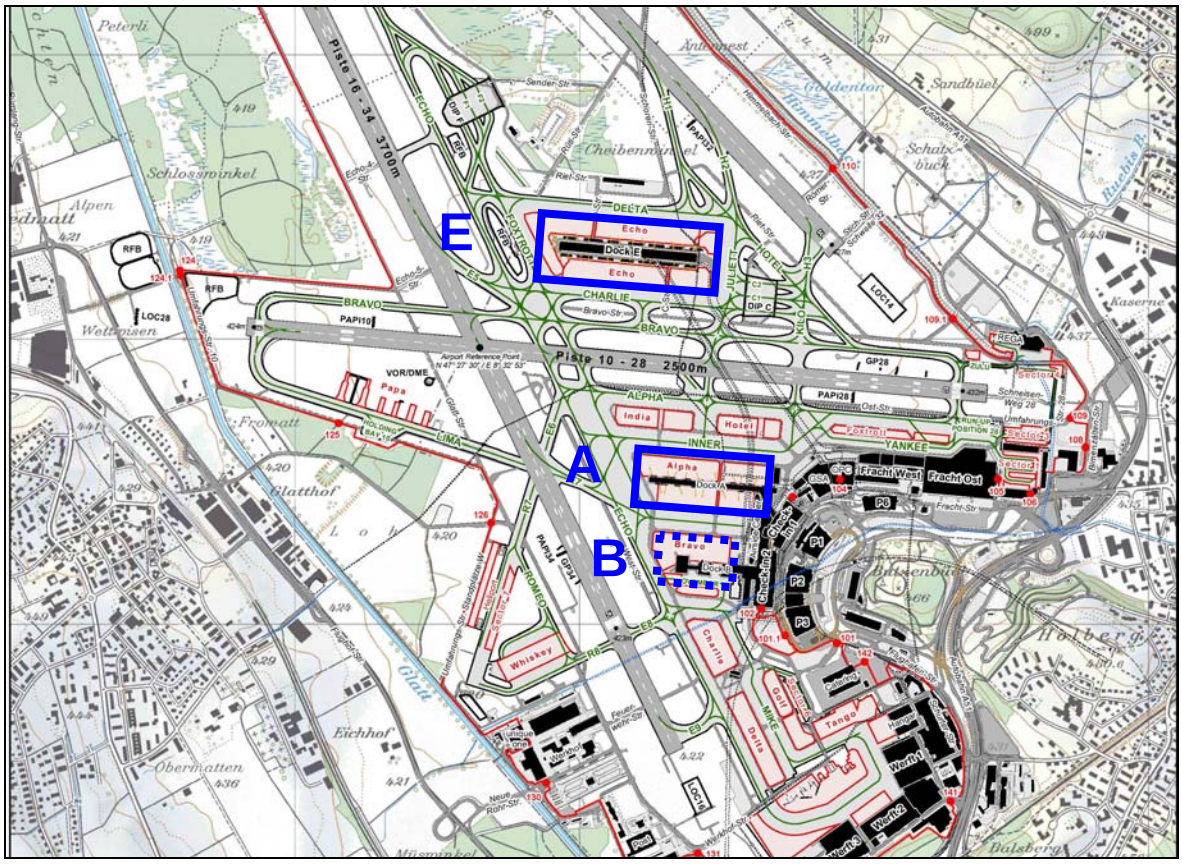


Figure 2: Zurich airport aircraft concourses and hard stands: Pier A, E, former/future B

Reflecting the ambient and climate conditions of Zurich airport, the systems for pre-conditioned air are designed for the following:

- Ambient conditions: Summer: +31°C, 80% humidity
  Winter: -11°C, 40% humidity
- Cabin conditions: Summer: +26°C
  Winter: +21°C

3 Technical Description

3.1 Pier E

3.1.1 Electrical System 400 Hz

Pier E went into operation in 2003 and provides 27 gates for aircraft handling. 16 gates are for aircraft categories D and E (180 KVA) and 11 gates for category C (90 KVA). The static converters are placed in the apron buildings. Depending on the stand size, one or two converters are available. The cable coils with 30 m cable are mounted underneath the passenger loading bridge.

The operation of the system can be done through the aircraft plug or the switch board on the passenger loading bridge. For open handling, four pit systems are available.

The system contains a monitoring and control unit with 2,500 data points. The system logs all operating events and system errors and all important data can be analysed and evaluated. The temperatures of the various phases are measured in the 400 Hz plugs and three gates are equipped with measurement systems for the electricity.

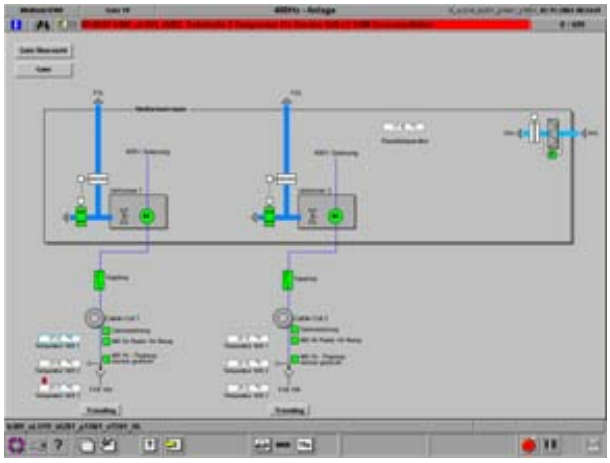


Table 2: Technical data 400 Hz system Pier E

		Comments
Gates Pier E	27	16 x 180KVA 11 x 90KVA
Transformer station	2 1	2 x 1,600 KVA 1 x 700 KW (cooling)
Static converter 90KVA	45	Total capacity 4.05 MVA
Reserve for converter NLA (new large aircraft)	4	2 gates with 360KVA
Cable coils	43	
PIT Systems	4	

3.1.2 Pre-conditioned Air System

The air-conditioning units deliver warm or cold air to the aircraft fuselage depending on the requirements. The air units are placed on the apron and connected to the hose reels over a telescope pipe under the passenger loading bridges. The gates for category D and E aircraft have two hoses, the gates for category C aircraft one.

The ice machines produce binary ice (flow-ice) during the night wich is stored in the energy storage unit. During actual operations, the stored energy is sufficient for a standard day of operation. This results in lower energy capacity requirements as peak hour demand has not to be met. Also, binary ice requires smaller transport pipes as the latent energy can be used. The gates provide metering systems to monitor heat and ice consumption of individual aircraft types.

The heating and cooling energy is provided through two separate pipe systems at each gate. This enables to heat or cool aircraft at the same time. All relevant data are displayed in the control system for analysis and evaluation.

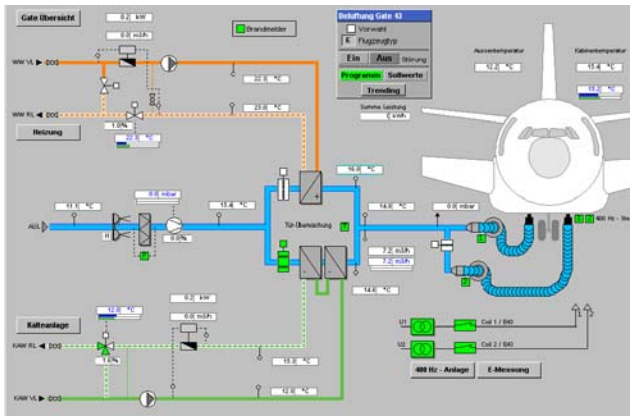


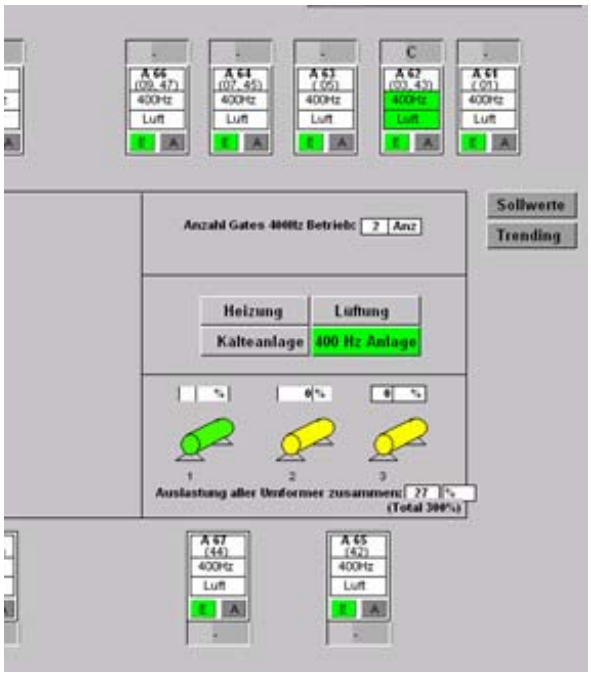
Table 3: Technical data PCA Pier E

		Capacity
Ice machines (ammonium)	2	2 x 410 KW
Ice Storage Stored Energy	1	220 m^3 10,000 MWh
Heating Transformer	2	1,100 KW each
Air Conditioning Units (two hoses)	16	12,000 m^3/h
Heating capacity per unit		190 KW
Cooling capacity per unit		225 KW
Air Conditioning Units (one hose)	11	6,000 m^3/h
Heating capacity per unit		80 KW
Cooling capacity per unit		105 KW

3.2 Pier A

3.2.1 Electrical System 400 Hz

Pier A went into operation in 1985 and has a total of 18 stands for the handling of aircraft. When handling wide-body aircraft, the number of stands is limited to 13.



The production is central with three rotating 50/400 Hz converter that are each switched on or off depending on the demand at the gates. The distribution to the individual gates is done via the 960 V grid. Each gate is equipped with 90 KVA transformers and contains a 400 Hz cable with plug. For wide-body aircraft, a so called "Y"-cable is used that distributes the electricity to both aircraft plugs.

A specialty of the plant is the monitoring and control system with 1,500 data points. This control system logs all operating events and system errors. All important data are trend analysed and evaluated.

Table 4: Technical and operational information 400 Hz Pier A

		Comments
Gates Pier A	18	Built 1985
Transformer Station		
Converter 300KVA Manufacturer	3	Total capacity: 900 KVA Piller
Distribution	960V / 400 Hz	
Currency Compensation Gate	none	
Local Transformer	18	90 KVA

3.2.2 Pre-conditioned Air System

The pre-conditioned air system for Pier A as it is today went into operation in 1998. Up to that time, air pressure compressors have been used for air-conditioning and main engine start. The system operates the same way as the one in pier E. However, pier A only offers one hose per gate for air-conditioning. The air units have different capacities depending on the gate size.

Table 5: Technical data PCA Pier A

	Number	Capacity
Ice Machines	2	2 x 475 KW
Chiller Storage Capacity Stored Energy	9	 1'050 KW 4 MWh
Heating Converter	2	900 KW each
Air conditioning units (two hoses)	13	10,000 m^3/h
Heating capacity per unit		190 KW
Cooling capacity per unit		225 KW
Air conditioning units (one hose)	5	5,000 m^3/h
Heating capacity per unit		80 KW
Cooling capacity per unit		105 KW

3.3 Pier B

Pier B went into operation in 1975 and has 10 aircraft gates. It is currently out of service for major refurbishment and all 400Hz and PCA systems have been decommissioned. In previous years, some stands have still been used for long term parking of aircraft and five 400 Hz system remained in operation for this purpose.

4 System Operation

4.1 Energy Production

Energy is provided for all systems by the airport's central power plant. This energy plant is a combined heat and power co-generation plant, consisting of four boilers with two steam turbines and one gas turbine with a total heat capacity of 120 MW_{th} and 10 MW_{el}. The plant is operated with 90% compressed natural gas (since 1998) and 10% heating oil (light). It provides the whole airport with process energy and is optimised for operational and ecological parameters.

Electrical energy is taken from the public grid through two independent transformer stations.

4.2 Operations

The systems are owned and maintained by Unique (Flughafen Zurich AG) as part of the core infrastructure of the airport. The systems are operated by the various handling agents. When an aircraft approaches the parking position, ground staff sets the chocks and hooks up the aircraft to external power at the same time. As such it is not necessary for the aircraft crew to run the APU upon approaching the stand in order to timely shut down the main engines. Power is switched from main engines directly to external.

The technical availability of the system is >99% of all times. Both, the technical availability of the systems and the immediate service provided to the arriving aircraft are key to the acceptance by the flight crews and thus the effectivity of the system. Maximizing the use of the system and thus the ecological benefits is further enhanced by implemented and enforced local regulations (cf. chapter 5).

Average operating data from 2004 to 2006 are listed in table 6. The average total LTO cycles were 133,500 per year.

Table 6: Average annual operating data for Fixed Energy Systems (2004-2006) and average 2005-2008[1]

	Pier A	Pier B	Pier E	Total
Equipped gates	18	5	27	49
Aircraft cycles handled	30,000	400	31,000	61,400
400 Hz Usage per gate[1]	8 h/d	1.5 h/d	6 h/d	
PCA Usage per gate[1]	1.1 h/d	--	1.6 h/d	
Billed hours 400Hz	43,000 h	3,000 h	60,000 h	106,000 h
Billed hours PCA	5,300 h	0 h	16,000 h	21,300 h
Electricity 400 Hz[1]	1,300 MWh	300 MWh	2,000 MWh	3,600 MWh
Electricity PCA[1]	350 MWh	0 MWh	800 MWh	1,150 MWh
Electricity Total[1]	1,650 MWh	300 MWh	2,800 MWh	4,750 MWh
Heat consumption	200 MWh	0 MWh	300 MWh	500 MWh

5 Aircraft APU Operational Restrictions

Based on articles 36 and 51 of the Operating License for Zurich Airport (of 1.6.2001), the use of auxiliary power units (APU) is subject to certain restrictions. These are laid down in the AIP LSZH, section AD 2:

AIP SWITZERLAND[1]
LSZH AD 2

2.21.2.5 Auxiliary Power Units (APU)
Docking Stands
Primarily, the stationary airport pneumatic and electrical service units shall be used. Alternatively, mobile units shall be used.

Other stands
For pneumatic and power supply of aircraft not parked at docking stands, mobile units shall be used.

APU shall only be started:
- To start engine, but earliest 5 minutes before off-block time.
- If maintenance work on the aircraft makes it unavoidable; in that case the service period shall be kept as short as possible.
- If the stationary or mobile units are not available or unserviceable for specific aircraft types. In that case the APU shall be started at earliest 60 minutes before off-block time and kept in operation not more than 20 minutes after the on-block time.

In particular cases, the Airport Manager of the Airport Authority may permit longer service periods.

Some airlines establish additional and company based procedures for the usage of APU. These procedures can be dependent on aircraft type, actual take-off weight and characterisation of the airport (altitude, runway length, etc).

One airline operating in and out of Zurich has established the following procedures (properly reflecting the airport's regulations):

4. USE OF APU
- Use of APU restricted.
  Use APU for ENG – start MAX 5 MIN before block off.
  If GPU U/S: Start APU MAX 60 MIN before block off.
  APU OPS MAX 20 MIN after block on.
  For A320 taxi-in without APU approved.
- ACFT on hard stands: switch off APU when GND Power Unit (GPU) connected.
- Terminal A/B: Preconditioned air and electrical power avbl.
- Energy saving:
  The crew shall decide, depending on WX COND or technical requirements, whether air conditioning is required or not.
  Generally, the air conditioning system should be switched off with AOT of APRX 10°C to 25°C. The air conditioning system should also be switched off after PSGR have disembarked or before leaving the ACFT.

[1] 31 OCT 2003 and AIRAC 15 APR 2004

6 Economics of the System

The required investments for 400Hz/PCA systems designed and implemented for Zurich airport are approximately 1 million Swiss francs (CHF) per gate; the costs are about 45% for the 400 Hz systems and 55% for the PCA system. The costs generally vary depending on the required service level and the possibility to plan one comprehensive system rather than upgrading an existing 400 Hz system with PCA.

The costs of service vary according to the services required and the handling agent providing the service. By way of information, table 7 gives an overview of the service charges at Zurich airport.

Table 7: Fixed system service prices at Zurich Airport (1.11.2008)

Aircraft Group	**400 Hz Electrical Energy (CHF/hour)**	**Pre-Conditioned Air (CHF/hour)**
Size A: RJ70, RJ100, B737, F70, F100, MD80	36.-	75.-
Size B: A300, A310 ,A319/20/21, B757, B767	62.-	130.-
Size C: A330, A340, B747, B777, MD11	87.-	190.-

Charging Rules:	
0-10 min.	no charge
11-70 min.	1.0 hour (=minimum charge)
71-100 min.	1.5 hours
101-131 min.	2.0 hours
131-160 min.	2.5 hours
etc.	

APU operating costs vary depending on the aircraft type, the APU type, APU fuel consumption and operating times as well as fuel price and other APU operating/maintenance costs. An approximation for fuel costs for APU operation only is given in table 8.

Table 8: Approximation of APU fuel costs (in CHF/h)

Aircraft Group	**APU Fuel (kg/h)[2]**	**Fuel Price (CHF/kg)[3]**	**Fuel Costs (CHF/h)**
Short haul aircraft	107	1.40	150.-
Long haul aircraft	240	1.40	336.-

Comparisons:

- A large aircraft (A330) using fixed 400Hz for 3 hours plus fixed PCA for 1 hour pays 451.- CHF for the service, while only the fuel costs for the APU over the same 3 hours are approximately 1,000.- CHF.
- A small aircraft (RJ100) using fixed 400Hz and PCA for 1 hour each pays CHF 111.- for the service, while the fuel costs only for the APU are approximately CHF 150.-

[2] ICAO Doc 9889, Version 1, Table A1.4.6

[3] IATA, Basis May 2008 (1,351 USD/mt)

7 Environmental Benefits

The combination of reliably providing electrical energy and pre-conditioned air while at the same time mandating the airlines to use the systems when technically available is key to achieve maximum ecological benefits.

Already the specific emission reductions are considerable when comparing the CO_2 emissions per hour of operation for an APU and the fixed energy system (table 9).

Table 9: Specific CO_2-emissions (kg/h)

	APU kg CO_2/h	**FES kg CO_2/h[1]**
Shorthaul Aircraft	337	0.7
Longhaul Aircraft	758	1.2

[1]Emissions from Swiss electricity production

The benefits of the fixed ground power systems are convincing: In 2007, the use of the fixed energy system has reduced the airport emissions by 86 t NOx and approximately 44,000 t CO_2 (equals almost 14,000 t of fuel worth 19.5 million CHF)

Table 10: Emission reduction Zurich airport in 2007

	2007	
Total Movements	268,476	
Operation with FES/GPU (actual)		
Total Airport NOx	1,014 t	
APU NOx	21 t	(2.1%)
Total Airport CO_2	305,340 t	
APU CO_2	11,554 t	(3.8%)
Operation with APU only (scenario)		
Total Airport NOx	1,096 t	
APU NOx	103 t	(9.4%)
Total airport CO_2	338,800 t	
APU CO_2	45,000 t	(13.3%)

Total airport emissions include[4]:

- Performanced based aircraft emission with ICAO data;
- Handling emissions (GSE, airside traffic, aircraft maintenance)
- Infrastructure (energy plant, emergency generators, airfield maintenance, construction, fire training)
- Land side vehicle traffic (access traffic to airport within local perimeter of approx. 3 km)

[4] Calculation methods Zurich airport 2008.

8 Annex

8.1 Abbreviations

ACFT	Aircraft
ACU	Air Climate Unit
AOT	Ambient Outside Temperature
APRX	Approximate
APU	Auxiliary Power Unit
ASU	Air Starter Unit
CHF	Swiss Francs
CO_2	Carbon Dioxide
ECS	Environmental Control System
EGT	Exhaust Gas Temperature
ENG	Engine
FES	Fixed Energy System
GPU	Ground Power Unit
GSE	Ground Support Equipment
hp	Horsepower
Hz	Hertz
ICAO	International Civil Aviation Organization
IGV	Inlet Guide Valves
kW	Kilowatt
LTO	Landing and Take-off Cycle (standard 4 modes)
MES	Main Engine Start
NOx	Oxides of Nitrogen
mt	metric ton
MWh	Megawatt-hours
OPS	Operations
PCA	Pre-conditioned Air
PSGR	Passengers
V	Volts
WX COND	Weather Conditions

8.2 References

AIP, 2004: *Aeronautical Information Publication Zurich Airport*. Unique (Flughafen Zurich AG), Zurich, 2004.

ICAO: Local Air Quality Guidance Manual, ICOA Doc. 9889 (1st Edition, 2007).

Unique (Flughafen Zürich AG): Emission Charges Zurich Airport. Review 2003. Zurich, 2003

Unique (Flughafen Zürich AG): Energy Management Zurich Airport. Zurich, 2005

Unique (Flughafen Zürich AG): Aircraft APU Emissions at Zurich Airport. Zurich, 2005