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Multi-year consumption analysis and innovative energy perspectives: The case study of Leonardo da Vinci International Airport of Rome

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ABSTRACT

Because of the growing need for efficient energy production systems, energy policies promoted in recent years have also involved complex structures, like airports. This paper proposes the implementation of an energy management system for a very energy-consuming structure, composed of different power plants and many energy consumers: the Leonardo da Vinci International Airport of Rome. In this study, the examination of historical data related to airport electric power, thermal energy and fuel consumption is discussed, starting with the analysis of the production energy plants, mainly based on a combined heat and power system. Furthermore, pioneering solutions are proposed, not only to cover airport energy requirements, but also to test the safety and reliability of innovative load management systems. For this reason, the choice of the Leonardo da Vinci management company, oriented to install a smart storage in order to manage the bidirectional energy flows by consumers and producers, is justified. Such innovative energy procurement systems are examined, with the goal of achieving greater penetration of renewable sources: mini and micro wind power plants and high concentrator photovoltaic plants.

1. Introduction

Energy efficiency is a key issue for the energy policies of the most industrialized countries, because of its central role in economic, technological and social growth.

Currently, considering the high need for energy sources, attention to environmental sustainability and the economic downturn, expectations of progress in energy efficiency are increasing. Energy efficiency represents an essential element for achieving environmental objectives, for the optimization of expenditure needed to cover the energy requirements and, lastly, to achieve adequate levels of energy security.

The rapid technological and industrial development of the last few years has generated an increase in the consumption of fossil fuels with consequences for the environment, creating in turn a clear interest for energy systems less dependent on traditional energy sources [1].

The European Union spends a lot of its funds for research aimed at satisfying greater energy efficiency policies, and issuing directives aimed at energy efficiency, such as Directive 2012/27/EU [2], which was transposed in Italy by Legislative Decree 102/2014 [3]. In Europe, about 75% of the energy consumed [4] is derived from fossil fuels and for many European countries, including Italy, there is also the problem of energy supply, which means dependency on energy-producing countries.

The reduction of buildings energy consumption runs in two parallel directions. On one hand, through a decrease in thermal needs, obtainable by increasing thermal performance of the structural elements. On the other hand, through the increase in performance of the plants that satisfy energy requirements. Nowadays, energetic retrofit methods are supported by innovative techniques [5], that allow rapid and complete assessment of thermal behavior of building's envelope. Furthermore, the complexity of retrofit techniques calls for the definition of holistic approaches, as discussed for non-residential lighting and daylighting retrofit in practice [6].

Energy losses of buildings, high electrical loads, lighting and electrical equipment and complex air-conditioning systems make airports extremely energy-intensive areas, with significant contemporary loads. At the same time, the high incidence of the absolute value of energy consumption calls for great improvements on

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Nomenclature

A	scale parameter of Weibull distribution [m/s]
ADR	Aeroporti di Roma company
CHCP	combined heat cooling and power
CHP	combined heat and power
CPV	concentrator photovoltaic
EMS	energy management system
ENAC	Italian civil aviation authority
HCPV	high concentrator photovoltaic
IEC	international electrotechnical commission
k	shape parameter of Weibull distribution, dimensionless
LCPV	low concentrator photovoltaic
LDVIA	Leonardo da Vinci international airport
MCPV	medium concentrator photovoltaic
$p(v)$	probability density function
RTU	remote terminal unit
SCADA	supervisory control and data acquisition
SCR	selective catalyst reduction
toe	tonnes of oil equivalent
v	wind velocity [m/s]

the energy production and management systems [7]. Low-cost interventions, dedicated to the reduction of energy inefficiencies, as well as more expensive interventions, based on the installation of innovative energy systems, could be proposed.

Many studies and technological proposals have been published, focused on the reduction of the huge energy consumption, to enhance airports energy efficiency. For example, with the aim of analyzing the influence of the desiccant wheel on the performance of an air conditioning system, Ruivo et al. [8] conducted dynamic simulation of an airport located in the Mediterranean climate. Leung et al. [9] developed an innovative water resource management system for the integration of seawater and grey water reuse, demonstrating the applicability of this novel system at the Hong Kong International Airport. Fontela et al. presented a project based on an hybrid electric vehicle prototype for the airport sector; a new propulsion system based on electric motor and hydrogen fuel cell, to analyze the advantages regarding autonomy, charging time, efficiency and emissions, with respect to the existing vehicles [10]. An innovative idea to convert the kinetic energy stored in landing aircraft is presented by Zhong [11]. In his study, results about the electricity generated, obtained by simulations, are shown.

In the field of solar energy, Rüther and Brown [12] analyzed the integration of solar photovoltaic systems on airport buildings in warm climate to study the energetic contribution potential with respect to the entire electric power consumption of an airport. On the basis of simulation and measured data, Araki et al. [13] presented the evaluation of yearly electric generation of a bifacial photovoltaic system in Aichi Airport. Furthermore, Zomer et al. [14] studied a performance compromise between building-integrated and building-applied photovoltaic in Brazilian airports.

Rowlings et al. proposed various types of sustainable energy sources for the airport facilities: hydropower, biomass, solar, wind and geothermal energy [15].

Finally, other studies focused the analyses on the reduction of the air pollutant emissions that represent a consequence of energy efficiency interventions. Simões and Schaeffer [16] discussed the level of participation of Brazilian air transportation sector in the context of global climate change. Turgut et al. presented an assessment of emissions by selecting eight different busy airports [17].

The aim of this paper is to propose the implementation of an energy management system for an articulated structure, particularly significant for its intended use, and energetically complex: the Leonardo da Vinci International Airport of Rome (Italy), which has self-production energy plants and all of the services that characterize a small-sized city. This paper presents the analysis of the energy technologies installed in the Leonardo da Vinci International Airport, and a multi-year overall energy consumption analysis. These analyses were performed through a management model, that divides the airport in different areas: for each area, the corresponding consumption (electric, thermal or fuel) is associated and analyzed, allowing the identification of the most energy-consuming sectors. In this way, interventions aimed at improving the energy performance can be properly directed, reducing the uncertainty of their effects.

Moreover, energy efficiency measures are proposed, strongly aimed at optimal energy management and to the use of renewable energy sources: the "Smart Grid" prototype project for the T1 Terminal is presented. The aim of the "Smart Grid" project is to test the storage capacity and the load management of the Smart Storage, finding an optimum point between energy produced by renewable systems and energy consumed.

Therefore, management system dealing with complex energy fluxes of a big strategic facility in the context of EU and use of renewable energy sources to test a Smart Grid, can offer a significant and useful case study.

2. Methods

In general terms, complex structures are characterised by numerous energy producing centres and multiple centres of consumption, which are differentiated by the quantity of energy absorbed and by the type of energy required. In fact complex structures generally require different forms of energy: electricity (e.g. for lighting), thermal energy (e.g. for heating of buildings) and fuel (e.g. for transport). Therefore the energy management of such structures requires management models able to monitor energy produced and consumed with the aim of identifying the high consuming areas and eventual anomalies of the system. The identification of high consuming areas will permit the introduction of suitable measures to improve energy efficiency reducing uncertainty in the obtainable results.

Fig. 1 illustrates a systematic approach, which allows the optimisation of energy management through the identification, analysis and implementation of all energy flows. This model has been applied for the management of a complex structure such as an airport, but could also be extended to small towns.

2.1. Leonardo da Vinci International Airport description

The Leonardo da Vinci International Airport (LDVIA) is located in Fiumicino, about 28 km from the Rome city centre. It is Italy's major airport and one of the most important in Europe, based on the total number of passengers using the facility [18]. At its inauguration, on January 15th, 1961, the airport had two runways; it replaced Ciampino airport, which subsequently was used for domestic and charter flights [19]. Nowadays, the LDVIA is the reference "Hub" for scheduled international and intercontinental flights and charter flights in Italy.

Currently, the airport has four runways and four terminals (T1, T2, T3, T5), where the check-in islands, baggage handling facilities,