INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2017) 1–13

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

Measuring global effectiveness of integrated electric energy systems

Jesus Maria Larrañaga Lesaca [a,*], Ekaitz Zulueta Guerrero [b], Jose Manuel Lopez-Guede [b], Josean Ramos-Hernanz [c], Ana Larrañaga Juaristi [d], Ortzi Akizu [e]

[a] Basque Country University (UPV/EHU), Faculty of Engineering of Vitoria, Dept. of Business Management, C/Nieves Cano 12, Vitoria, 01006, Spain

[b] Basque Country University (UPV/EHU), Faculty of Engineering of Vitoria, Systems Engineering and Automatic Control Department, C/Nieves Cano 12, Vitoria, 01006, Spain

[c] Basque Country University (UPV/EHU), Faculty of Engineering Vitoria, Electrical Engineering Department, C/Nieves Cano 12, Vitoria, 01006, Spain

[d] CESA Vitoria, Paseo del Batan 60, 01007, Vitoria, Spain

[e] Basque Country University (UPV/EHU), Faculty of Engineering Vitoria, Graphic Expression and Engineering Projects Department, Nieves Cano 12, 01006 Vitoria-Gasteiz, Spain

ARTICLE INFO

Article history:
Received 1 December 2016
Received in revised form
22 March 2017
Accepted 7 April 2017
Available online xxx

Keywords:
Measuring global effectiveness
Planning Factor
Overall Equipment Effectiveness
OEE
Modelling two sided power
TSP

ABSTRACT

In the energy sector, significant investments were made to improve the characteristics of the existing integrated electrical system favoring the transition to a more sustainable, efficient, flexible, reliable and high quality system. Therefore, it is required to have reliable and robust metrics that try to include these concepts in the form of indicators for the KPI and its subsequent analysis. This paper addresses that problem and in order to tackle it introduces a novel methodology to measure the effectiveness of an integrated electrical system. Such methodology is based on the extension of the OEE concept to the energetic domain considering the multiple uncertain factors affecting OEE, and establishing a relation among them through the Planning Factor (PF), which relate strategic and operational concepts. In the experimental part of the paper, we have used this novel methodology to analyze and measure the effectiveness of the Spanish integrated electrical system without losing generality, and using a confidence interval of 95% an OOEE of 0.96 and SOEE of 0.652 have been obtained, which classifies the Spanish system as an advanced one. In this way, different settings or electrical systems can be compared an assessed.

Introduction

In 2007 Google launched a project named “RE < C” (Renewable Energy cheaper than Coal) directed by David Fork and Ross Koningstein in order to obtain a zero-emission CO_2 energy, besides, it should be cheaper than coal-generated electricity. Although the project was abandoned in 2011, the reached conclusions were remarkable. With the aim of analyzing the potential of the renewable energies, in that project a number

* Corresponding author.

http://dx.doi.org/10.1016/j.ijhydene.2017.04.057
0360-3199/

Notation

Beta-Pert	Distribution Beta for Pert
cdf	Cumulative distribution function
CLT	Central Limit Theorem
KPI	Key Performance Indicator
LCOE	Levelized cost of energy production
MPT	Mantenimiento Productivo Total
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
MW	Megawatt
MWh	Megawatt-hour
SOEE	Strategic Overall Equipment Effectiveness
OOEE	Operational Overall Equipment Effectiveness
pdf	Probability density function
PF	Planing Factor
PUP	Provisional Useful Program
TPM	Total Productive Maintenance
TSP	Two Sided Power

of different scenarios of actual zero-emission technologies (solar CSP, solar PV, wind, geothermal energy, energy storage, etc.) was simulated over the next decades. In Table 1 we can see shows the most optimistic scenario, where the project concluded that there should be relevant declines in the cost of zero-emission technologies. For example, by 2020 the Levelized Cost of Energy Production (LCOE) should capture between 36% and 71%, while between 56% and 86% by 2050.

In the specific case of the energy sector, there has been a change in the model of production and consumption. The main objectives established in any energy policy are to ensure the supply guarantee (coverage of demand) and the environmental quality, on all counts [1].

To this end, profound structural changes have been undertaken in order to achieve greater sustainability of the system, from the perspective of energy consumption and demand, as well as from an environmental and emission perspective. The incorporation of intermittent energies, such as wind power, independent of demand [2] into the system has been important and contributes to the greater difficulty managing these types of energy.

Automation and control systems were incorporated into the existing electricity transmission and distribution networks. So, its state at all times is known, with the objective of transforming the electrical network into a resistant and interactive service network, controlling the flow of information and exchange of real-time data in order to optimize the adjustment of the generation and demand curves, and eliminating obstacles to use distributed or intermittent generation systems, such as renewable, microgeneration, fuel cells, etc. [3,4].

The incorporation of information technologies allows optimizing the relationship among consumers, energy producers and generation points. These networks have three layers, i.e., physical layer of production, transport layer, communication and control, and finally the layer of applications and services, which increase the operating efficiency of the system and the conditions of transmission and distribution by detecting faults and assuring the quality of the service.

Thereby, the active management of the demand allows to adapt the installed power to fulfill the needs, equating in each moment the generation to the necessary power, giving not only answer to the peaks of consumption, but also providing better coverage to all the final energetic services [5]. In addition, it also contributes to the optimization of consumption patterns, satisfying the needs without loss of quality of supply through real-time network predictive management tools.

The *Smart Grids* systems operation has enabled significant reductions of the necessary investments in network and generation infrastructures to cover the demand, the costs arising from system disturbances or failures and the reduction of the costs of production. Moreover, the reliability of the system has been improved, as the intelligent networks have the capacity for self-diagnosis and self-recovery, so the system losses have been significantly reduced [6].

Nevertheless, if any parameter is critical for the improvement of smart grids and distributed generation, especially from renewable sources, is the development of advanced storage technologies over the last ten years. Systems that store large amounts of energy efficiently for the time needed to continue to cover the necessary services are available. The impact of the development of the electric vehicle and its influence on the demand curve facilitates the integration of the renewable energies and contributes to guarantee the operation of the network and the electrical coverage avoiding discontinuities in the supply or blackouts, always giving good response to the peaks of demand [7,8].

Finally, the strategies of international collaboration and the investments carried out have made possible

Table 1 – LCOE values assuming of the most optimistic scenario of the "RE < C" project (LCOE in $/MWh).

	OnShore wind	OffShore wind	Solar PV	Solar CSP+	Geothermal energy	Nuclear	CCS*	Storage
2010	73	198	157	204	78	78	–	300–500
2020	47	60	45	64	45	43	53	200–300
2030	35	48	29	43	33	37	44	100–250
2040	31	43	23	37	29	35	42	–
2050	29	42	22	35	29	34	41	70–200
Gap to:								
2020	36%	70%	71%	69%	42%	45%	–	33%–40%
2050	60%	79%	86%	83%	63%	56%	–	60%–77%

CSP*: Concentrating Solar Power.
CCS*: Carbon capture and storage.

Please cite this article in press as: Larrañaga Lesaca JM, et al., Measuring global effectiveness of integrated electric energy systems, International Journal of Hydrogen Energy (2017), http://dx.doi.org/10.1016/j.ijhydene.2017.04.057