

## Currents' Physical Components (CPC) concept in wind farm harmonic current studies

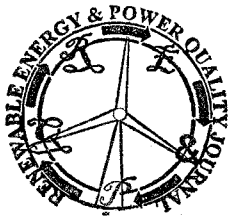
L. Sainz<sup>1</sup> and J. Cunill-Solà<sup>2</sup>

<sup>1</sup> Department of Electrical Engineering  
E.T.S.E.I.B., Technical University of Catalonia (UPC)  
Av. Diagonal 647, 08028 Barcelona (Spain)

Phone/Fax number:+0034 93 4011759/+0034 93 4017433, e-mail: [sainz@ee.upc.edu](mailto:sainz@ee.upc.edu)

<sup>2</sup> Department of Electrical Engineering  
E.P.S.E.M., Technical University of Catalonia (UPC)  
Av. de les Bases 61-73, 08240 Manresa (Spain)

Phone/Fax number:+0034 93 8777263/+0034 93 8777202, e-mail: [cunill@ee.upc.edu](mailto:cunill@ee.upc.edu)



**Abstract.** Very little information about actual wind farm harmonic measurements is available in the literature. This paper analyzes the harmonic measurements of an 18 MW wind farm with the CPC concept to determine if they are consumed or injected by the wind farm and to study the different reactive power definitions. The CPC concept is an approach to power theory that provides a physical interpretation of power phenomena in electrical systems with linear, time-invariant (LTI) loads and harmonic generating loads (HGLs) such as wind farms.

### Key words

Wind power generation, harmonics, power theory.

### 1. Introduction

The increasing number of wind farms worldwide causes power quality problems such as harmonic current emissions [1]-[6]. These emissions produce voltage distortion in networks, and their measurement and inclusion in WT power certificates are therefore required by current standards [7], [8]. Knowledge of these emissions is fundamental to study the influence of wind farms on network harmonic distortion. Although they are a well-known topic, very few studies based on actual measurements have been published [2]-[5]. Recently, the harmonic current behavior of an 18 MW wind farm was investigated from a large number of measurements in [9]. The wind farm harmonic emissions were studied, and the influence of the wind farm working point on these emissions was extensively analyzed. In addition, the probability density functions of the harmonic magnitudes and phase angles were discussed and compared in detail with analytical and empirical distributions in the literature.

Wind farm harmonics and, in particular, power transmission phenomena can be analyzed by the CPC concept. The CPC concept is currently the most advanced form of power theory of electric systems with periodic and semi-periodic voltages and currents. It explains power properties of single- and three-phase systems with LTI loads and HGLs [10]-[13].

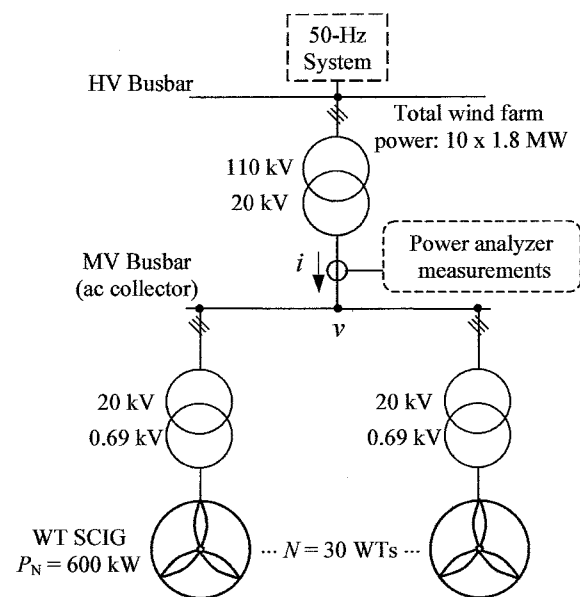


Fig. 1. One-line diagram of the wind farm.

The paper analyzes the harmonic current measurements in [9] and related power phenomena by the CPC concept.

### 2. Wind Farm Measurements

#### A. Wind Farm

The harmonic currents of the wind farm in the one-line diagram of Fig. 1 were extensively studied in [9]. The farm consists of 30x600 kW WT squirrel-cage induction generators (SCIGs) connected to the MV collector with 20/0.69 kV transformers. The rated power of the wind farm is  $P_N = 18$  MW and the rated current at the MV collector is  $I_N = 522$  A. A 110/20 kV transformer substation connects the MV and HV busbars.

#### B. Harmonic current measurements

Measurements were carried out at the wind farm MV collector (Fig. 1) with the power network analyzer AR5-L of CIRCUTOR (Fig. 2) according to the requirements of IEC 61400-21 [7] and IEC 61000-4-7 [8] standards. The analyzer has a 0.5% voltage and current