Renewable and Sustainable Energy Reviews 22 (2013) 73–80

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

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

Three-phase induction generators for single-phase power generation: An overview

Catalin Petrea Ion *, Corneliu Marinescu

PowerElma Research Laboratory, Transilvania University of Brasov, 1st Politehnicii Street, 500024 Brasov, Romania

ARTICLE INFO

Article history:
Received 10 September 2012
Received in revised form
7 January 2013
Accepted 14 January 2013
Available online 28 February 2013

Keywords:
Renewable energy
Induction generator
Phase balancing
Single-phase
Unbalances

ABSTRACT

The usage of three-phase induction generators for energy production in non-conventional energy systems covers a dynamic research area. When single-phase consumers are predominant, besides the use of a single-phase generator, a three-phase induction machine with a proper balancing circuit represents a reliable alternative.

Over the last 25 years, efforts have been made to enhance the balanced operation of a three-phase induction generator in single-phase mode. This paper presents a survey of the existing literature, focusing on several significant aspects such as phase balancing methods, excitation requirements, steady-state and dynamic analysis, and maximum available power in single-phase mode of operation.
© 2013 Elsevier Ltd. All rights reserved.

Contents

1. Introduction

Nowadays, renewable energy sources such as wind, solar and micro-hydro are increasingly being used for electric energy generation [1]. This aspect is determined on one hand by the depletion and environmental impact of conventional energy sources and on the other hand by the need to ensure clean energy for consumers located far from the distribution networks. In the case of low power micro-hydro plants an induction machine is mainly employed as generator. The literature concerning the autonomous operation of induction generators is very vast; a well documented survey can be of real help for researchers working in this field [2].

In many cases, isolated consumers require single-phase power; thus, the single-phase induction machine appears as a reliable alternative in supplying such consumers. A reasonable number of research articles can be found within this area of interest [3,4]. One of the main issues related to this generator is the choice of the capacitor(s) used to excite the machine. Different configurations have been presented in [5]: the simplest one relies on one capacitor across the auxiliary winding; another one has in addition

* Corresponding author. Tel.: +40 742566194.
E-mail address: catalin.ion@unitbv.ro (C.P. Ion).

1364-0321/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.rser.2013.01.031

one variable capacitor across the main winding, while the third one is completed with one more capacitor in series and a variable one in parallel with the main winding. The amount of required capacitance for excitation has been computed for shunt and series capacitors [6]. The steady state regime for shunt, short-shunt and long-shunt configurations has been analyzed in [7,8]; for the same regime the analysis has been done based on the harmonic balance technique [9] and on a model using graph theory and fuzzy logic [10]. The authors in [11] proposed the Newton–Raphson method to solve the nonlinear equations which resulted from the machine equivalent circuit. The method developed in [12] employed the symmetrical components analysis to obtain the equivalent circuit, while in [13] the effect of rotational direction is analyzed. Simulations have focused on the self-excitation process and voltage collapse [14] and on the behavior of a grid-connected generator during grid faults [15]. The stable operation in autonomous mode is ensured either by a single-phase ELC [16], by a single-phase PWM inverter supplied from batteries [17,18] or by a static VAR compensator based on thyristors [19].

However, the single-phase induction machine has a series of drawbacks with respect to a similar three-phase machine of the same power (it is more expensive, has lower efficiency and consequently a worse power per weight ratio); for series production, its power is limited to 3–4 kW. In the meantime, three-phase induction motors are available in a wide power range and models. Thus, efforts have been made to allow the operation of a three-phase induction generator in single-phase mode. This paper presents an overview of the existing literature in this field of interest. The paper is organized as follows: Section 2 presents the main phase balancing methods, while in Section 3 the excitation requirement for single-phase operation is analyzed. The steady-state and dynamic analysis for this particular operating regime is presented in Section 4 and the performance evaluation and maximum available power in single-phase mode are addressed in Section 5.

2. Phase balancing methods

The main characteristic of a three-phase induction generator supplying single-phase consumers is the unbalanced regime which cannot be allowed for stable operation. Either it operates in autonomous mode, or connected to a single-phase network, the generator requires phase balancing. Thus, the case in which the generator supplies three-phase balanced loads is replicated.

A brief chronological analysis shows that one of the early balancing methods focused on the three-phase induction generator operation on a single-phase grid. Ref. [20], one of the first articles in this field, proposes no less than four distinctive balancing configurations, three for star and one for delta connected induction generators. The balancing is done using passive circuit elements and employs either two capacitors, two capacitors and a unity turns ration transformer, three capacitors and a transformer, or, in the last case, two capacitors (connected in series and parallel). Another early solution introduced two shunt reactances, equal in magnitude, one being a purely inductive, while the other a purely capacitive element [21]. In parallel, the autonomous operation has been investigated as small generation units based on renewable energy sources (especially micro-hydro) have been requested to deliver single-phase power to isolated consumers. For instance, Ref. [22] was the first to introduce the "C–2C" term as balancing method for a delta connected generator, while Ref. [23] proposed the use of only one capacitor for self-excitation, for both star and delta connections.

From another perspective, the phase balancing topologies, generally named as "phase converters", can be divided into two major categories: based on passive circuit elements [24–57] (excitation capacitors, impedances) or on power electronic converters [58–67]. For the first balancing method the resulting configuration (and the number of requested capacitors) is imposed by the generator internal connection (star or delta); this aspect will be detailed in the paragraphs below. For each topology, a schematic representation is provided through Figs. 1–11.

2.1. Passive circuit elements

For star connected generators, the balancing topologies rely on:

- three capacitors, from which two of the same value, in the form of the Fukami connection [24–35] (Fig.1);
- three excitation capacitors in the form of the Smith connection and the re-arrangement of the stator winding [36–38] (Fig. 2);
- one capacitor, connected across one of the three phases, while the load is connected across the first phase; thus three configurations are possible [39,40] (see Fig. 3a); and
- one capacitor, connected either between two phases or across one phase, while the load is connected across two phases (see Fig. 3b); [41].

For delta connected generators, the balancing topologies rely on:

- one capacitor, connected in parallel with the load (this configuration is also called *single-phase mode of operation*—SPMO)

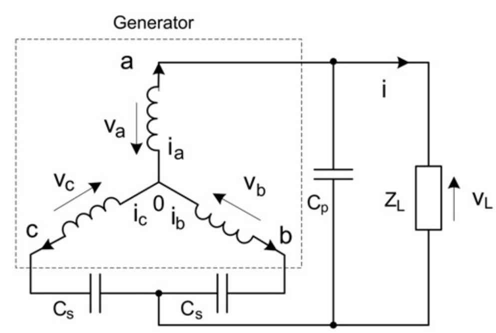

Fig. 1. The Fukami connection [24–35].

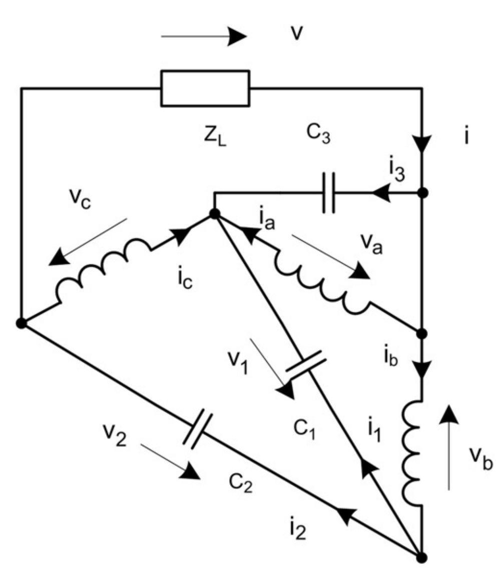

Fig. 2. The Smith connection [36–38].

Download English Version:

https://daneshyari.com/en/article/8121923

Download Persian Version:

https://daneshyari.com/article/8121923

Daneshyari.com