Renewable Energy 101 (2017) 1052–1066

Contents lists available at ScienceDirect

Renewable Energy

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

Effective performance and power transfer operation of a current controlled WRIG based WES in a hybrid grid

U. Sowmmiya*, G. Uma

Dept. of Electrical and Electronics Engg, College of Engg, Anna University, Guindy, Chennai, 600025, Tamilnadu, India

A R T I C L E I N F O

Article history:
Received 7 October 2015
Received in revised form
31 May 2016
Accepted 26 September 2016

Keywords:
DC micro grid
AC micro grid
WRIG
Rectification
Inversion

A B S T R A C T

This paper deals with the performance and possible power transfer modes of Wound Rotor Induction Generator (WRIG) based Wind Energy System (WES) in a hybrid grid (AC and DC Micro grid (DCM)) delivering power in islanded and utility tied conditions. The current controlled Rotor Side Converter (RSC) with its DC end connected to DCM facilitates bidirectional slip power flow. In islanded mode, a decoupled voltage vector control with cascaded PI loops is used for regulating stator voltage and stator frequency. In utility tied mode, reference current generation technique based on Instantaneous Power Theory (IPT) is adopted for slip power transfer by PWM rectification/inversion of RSC. The excitation is supplied via rotor and stator during islanded and utility tied conditions respectively. All possible operational modes are formulated aiming incessant power transfer by WRIG. Maximum power extraction during occasional situations like short circuit faults/low wind/overload and no load claims the merit of the system. The dynamic power transfer operation to maintain the power balance during hybrid mode is analyzed through laboratory experimentation on a 500 W induction machine. Experimental findings confirm the efficacious working of WRIG based WES.

1. Introduction

Utilization of renewable energy (RE) sources effectively reduces dependence on fossil fuels and increases reliability in supply. Among the green RE sources, wind is an imperative energy source to overcome the energy demand in areas with high wind velocity. Wind power can be supplied to loads when connected to isolated systems or can supplement utility when connected to grid. Owing to many renewable sources, power generation moves from large conventional power plants to small renewable power plants increasing the micro grids. Hybrid renewable micro grids are eco friendly, expandable and delivers uninterruptible power [1,2].

Focusing on power extraction from wind at all conditions, Self-Excited Induction Generator (SEIG) based systems were developed [3–5]. SEIGs gain fame owing to its rugged construction, simple maintenance and absence of brushes and slip rings. SEIGs supplying frequency sensitive loads suffer from torque oscillations, temperature effects and machine vibration. Owing to vibration less operation with frequency sensitive loads, enhanced performance, usage of reduced converters and bidirectional slip power extraction, WRIGs are attractive and are widely employed nowadays [6]. Grid connected WRIG dealt in Ref. [7] focuses on voltage regulation using mathematical model rather than power transfer. Grid connected DFIG in Refs. [8,9] details the operation at low wind with fractional converters. The method of power generation from variable speed DFIG in Ref. [10] focuses on harmonic mitigation rather than effective utilization of wind. All the above mentioned literature involves two converters connected back-to-back leading to increased cost and switching losses.

Micro grids in islanded operation offer the ability to effectively use renewable energy during grid outage. In any isolated WES, regulation of voltage and frequency is a confronting task. Moreover, isolated system needs to be reliable and should withstand dynamic wind speed/load changes. The system should be able to deliver power during all conditions so that wind power is better utilized rather than wasting it on some dump loads during adverse conditions. In order to extract the available wind power, the WES should be able to operate over a wide speed range. To achieve the above objectives, many control techniques are proposed in literature such as, slip control, vector control, direct torque/direct current/direct power control, Integral sliding-mode control etc., [11–18]. The control plan for the hybrid operation of micro grid discussed in

* Corresponding author.
E-mail addresses: sowmmeee@gmail.com (U. Sowmmiya), uma@annauniv.edu (G. Uma).

http://dx.doi.org/10.1016/j.renene.2016.09.068
0960-1481/

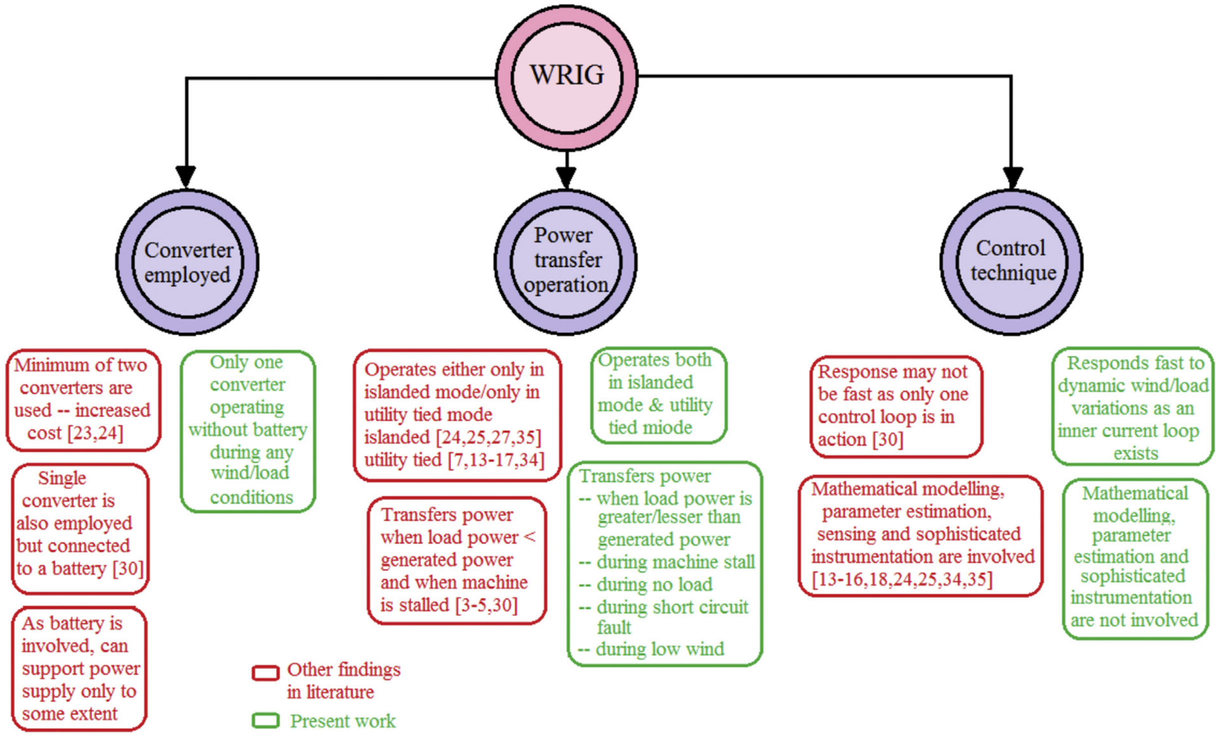

Fig. 1. Comparison between present work and other findings in literature.

Refs. [19,20] involve mathematical manipulation. A control strategy for the stable operation of micro grid with battery dealt in Refs. [21,22] has a limitation on charging. These control techniques for WRIG involve mathematical modeling, parameter estimation, sensing, and sophisticated instrumentation. Effective power supply operation even during adverse conditions is not possible.

A sensor less voltage control along with harmonic compensation discussed in Ref. [23] involves a four leg converter leading to additional cost. Sensor less speed control proposed in Ref. [24] involves frequency loops and machine oriented analysis. The autonomous power generation system with UPS function dealt in Ref. [25] is devoid of sensors but involve two converters. A current control approach discussed in Ref. [26] is applied to provide both voltage and frequency regulation. It involves an additional pitch control technique for improving the dynamic behavior of micro grid employing DFIG. The autonomous cascaded doubly fed induction generator (CDFIG) dealt in Ref. [27] operates in a variable speed constant frequency (VSCF) mode requires dynamic modeling of the system. The stand alone DFIG discussed in Ref. [28] focuses on autonomous frequency control rather than power supply at various conditions.

A WES feeding AC loads discussed in Refs. [29,30] aims mainly at harmonic elimination with the usage of a battery. Although effectiveness of storage and optimum energy storage techniques are dealt in literature [31,32] battery usage has a limitation on charging. Extraction of maximum wind energy in any autonomous system is essential to provide reliable power to load [33]. An autonomous wind farm employed with a quantitative analysis based control

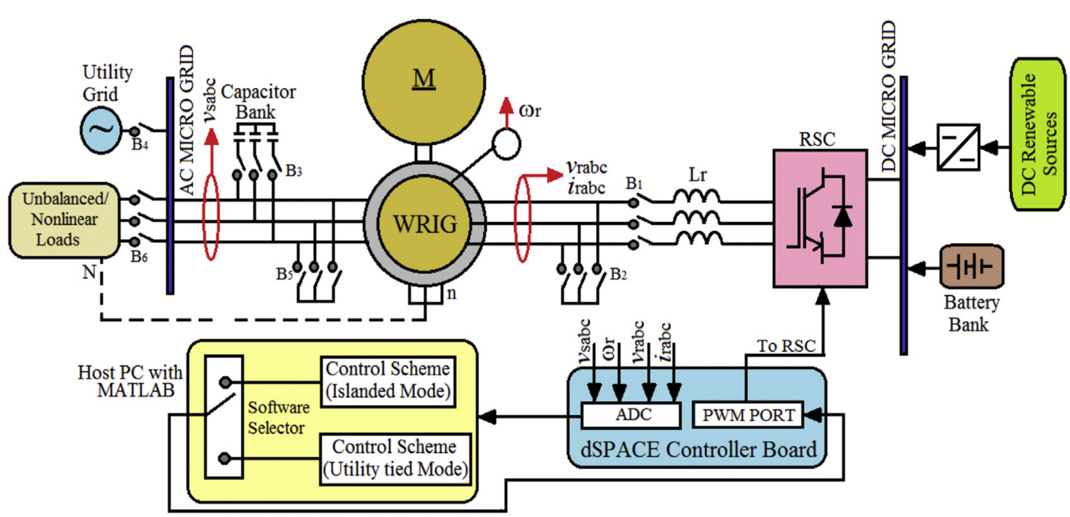

Fig. 2. Hybrid grid employing WRIG based WES.