A Review of VF Controller for an Asynchronous Generator Based Wind Energy Conversion System

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Abstract:

VF controller for wind energy conversion system employing a self-excited asynchronous generator, that has the capability for harmonic elimination, load balancing , and neutral current compensation along with voltage and frequency. This paper presents a review of VF controllers, other related economic and technical aspects, and their selection for specific applications. It is aimed at providing a broad perspectives or the status of VF controller for researchers and application engineers dealing with VF controlling issues. A list of more than 50 research publications on the subject is also appended for quick reference.

Keywords: Wind energy conversion system, self-excited asynchronous generator, four- leg voltage source converter (VSC) , three-leg VSC , three-phase four-wire system, two –leg VSC , Voltage and Frequency Controllers (VFCs)

1. Introduction

Remote located villages, islands, military equipment, ships, hilly areas, etc are the areas that are mainly isolated from the power system grid and required a generating system. However because of depletion of fossil fuels and concern about the global warming, the importance of locally available natural sources has increased such as wind, small hydro, biomass etc. In remote areas or isolated areas or hilly areas for harnessing electrical energy wind and hydro are best suited non-conventional energy source for supplying electric power in remote and isolated areas where grid supply is not accessible. An self-excited asynchronous generator (SEAG) [1]-[11], driven by the prime mover of the wind for supplying electricity in such areas by harnessing available non-conventional energy sources such as wind because in hilly areas or remote areas it is easily accessible in comparison to synchronous generator. If the synchronous generator is employed in the remote areas it may have so many problem, such as it needs frequent maintenance due to brushes ,it needs DC supply for excitation, and it is bound to be operated in synchronous speed.The primary advantage of self-excited asynchronous generator over the synchronous generator are brushless construction with squirrel cage rotor ,reduced maintenance, reduced size, less weight, no dc supply is needed ,self-short circuit protection [12],[13] , better transient performance. Because of these advantages it is used and it operates in the linear region of the core magnetizing curve, so that efficiency and performance can be upgraded. The main advantages of using this operation mode are: there is always margin to increase or to decrease the magnetizing flux, and consequently the generated voltage; overall efficiency is improved. In 1990s, a number of research papers were published on steady state and transient analysis of squirrel cage asynchronous generator –based standalone wind energy system [12]-[16]. However an asynchronous generator offers poor voltage regulation and its value depend on the prime mover speed, capacitor bank size and load characteristics. The major drawback of asynchronous generator is; frequency regulation under varying speed and load, poor voltage, reactive poor consumption. In the recently published literature [17] – [22] for standalone WECS employing a squirrel cage asynchronous generator, the battery energy storage system (BESS) with voltage source converter (VSC)-based voltage frequency controller is suggested for this isolated energy conversion system. An advantage of the BESS system is its bi-directional active power flow control can be achieved by controlling the frequency and there is no fuel consumption. The main challenges for the squirrel cage asynchronous generator-based WECS are the control of voltage and frequency. Therefore for satisfactory operation of WCES there is need of voltage and frequency controller.

In this paper a set of configurations of voltage frequency controllers (VFCs) for WECS using an asynchronous generator are presented. These controllers mainly consist of voltage source converters (VSCs) with a BESS at their DC link. These VFCs has the capability of having Bi-directional power flow i.e.; active and reactive power flow by which they can control both voltage and frequency under varying consumer load and velocity of wind. These VFCs also has the capability of eliminating harmonics and load balancing. [18]-[23]. There are the 3 section, the IInd section deals with the classification of VFCs for WECS for multiple functions as a VFC, such as a load balancer, a load leveller, a harmonic eliminator and a neutral current compensator. In the IIIrd section two types of control scheme are presented for WCES

2. Classification of VFC's.

There are various configuration of VFC is presented for an isolated asynchronous generator (IAG) driven by wind turbine .These VFCs are based on the VSC along with BESS. These VFCs are mainly classified to feed various types of three-phase three-wire or three -phase four -wire consumer loads shown in fig [1].

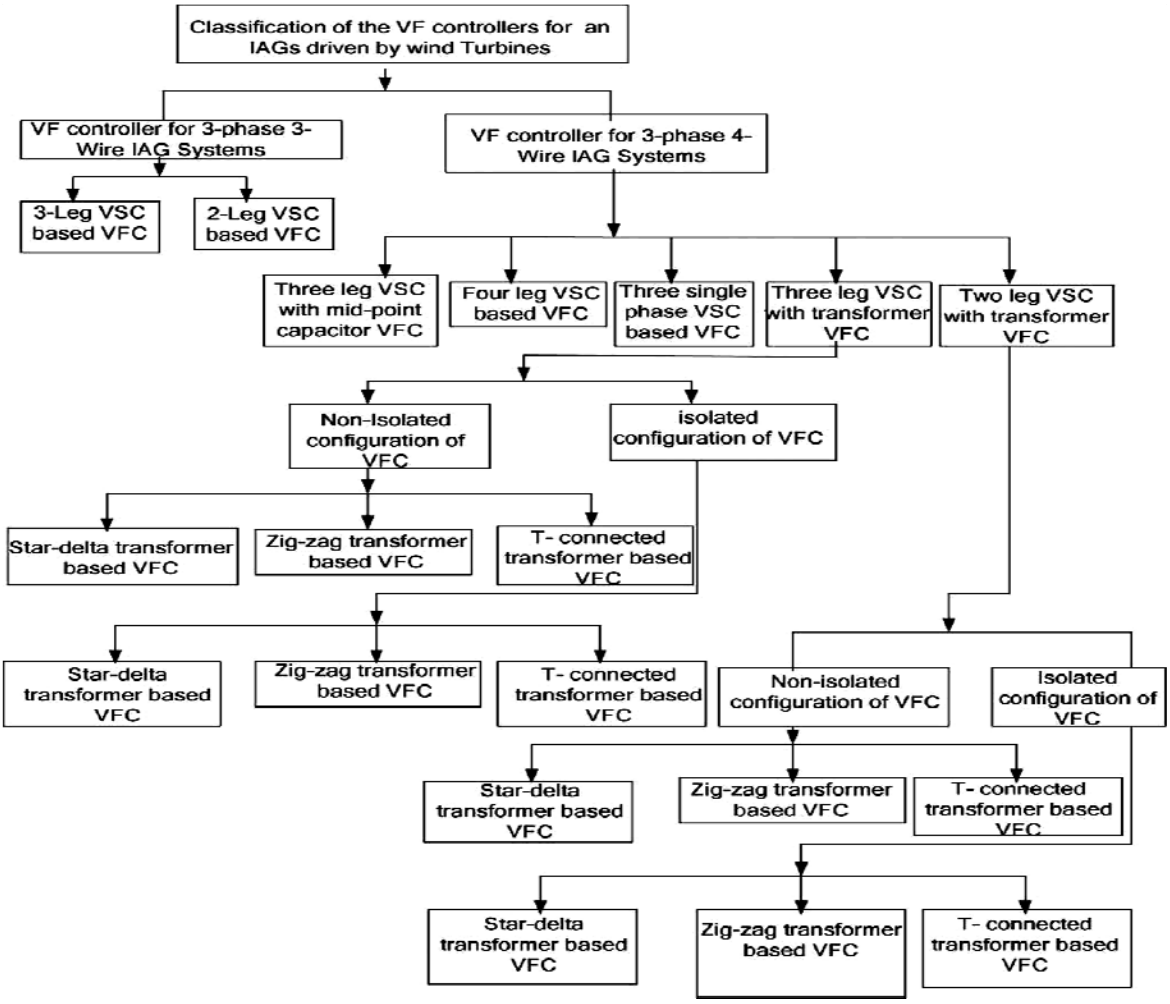

Fig. 1.Classification of VFCs for standalone wind power generating systems

2.1. *VFCs for Three-Phase Three-Wire IAG Systems*

Various types of three phase three-wire loads using IAGs are presented below

2.1.1. Three-Leg VSC-Based VFC:

The VFC shown in fig .2 consists of three –leg IGBTs based VSC with a, DC bus capacitor, DC chopper and AC inductors. The output of the VSC is connected through the AC filtering inductors to the IAGS terminal. The Dc bus capacitor is used to filter voltage ripples and provides self-supporting DC bus. The DC chopper is used to control surplus power into the controller due to change in consumer loads [27]. The excitation capacitor is selected to generate the rated voltage at no load while additional demand of reactive power is met by the controller. This VFC serves the purpose of harmonic elimination, load balancing, load leveling and reactive power compensation

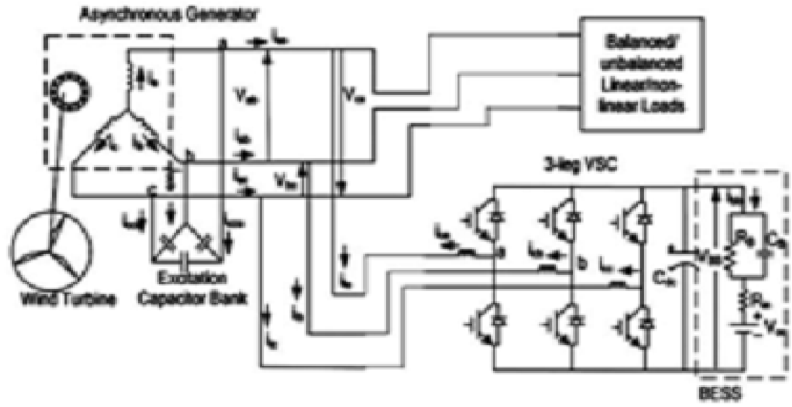

Fig. 2.Three-leg VSC with BESS-based VFC for a three-phase three-wire IAG system

2.1.2 Two-Leg VSC-Based VFC:

In this two-leg VSC-based VFC (see Fig. 3), two legs of VSC are connected to the two Phases and the third phase of the generator is connected to the midpoint of the capacitors which is connected in parallel to the BESS. In such a VFC configurations, it requires less number of switches.

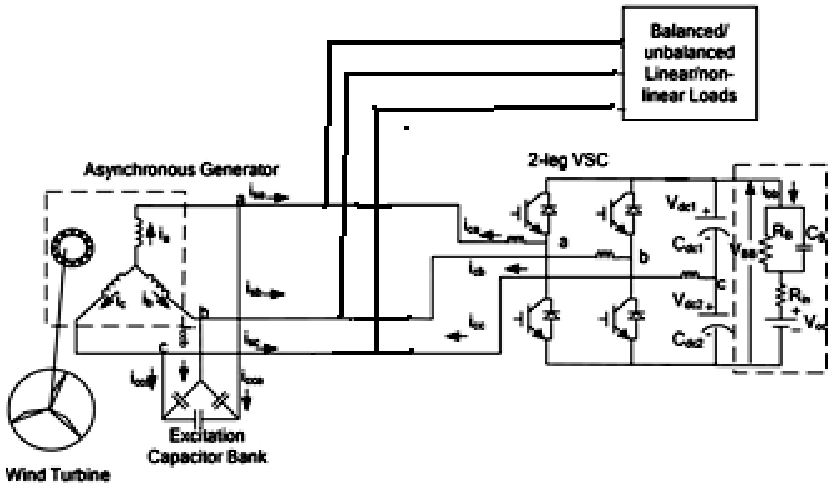

Fig. 3.Two-leg VSC with BESS-based VFC for a three-phase three-wire IAG system.

2.2. *VFCs for a Three-Phase Four-Wire IAG System*

Similar to VFCs for a three-phase three-wire IAG system VFCs for three-phase four- wire IAG system has various topologies of VSCs with BESS at its DC bus for VFC. The advantage of using this three-phase four-wire topology is that the voltage rating of the battery is selected at an optimum level and the transformer provides the path for flowing for neutral current.

2.2.1. Three Single-Phase VSC as a VFC:

This controller is consist of three single-phase IGBT-based voltage source converters VSCs with a battery at its DC bus with each VSC connected to each phase of the generator through single-phase transformer (see fig 4) [17],[18], [12]

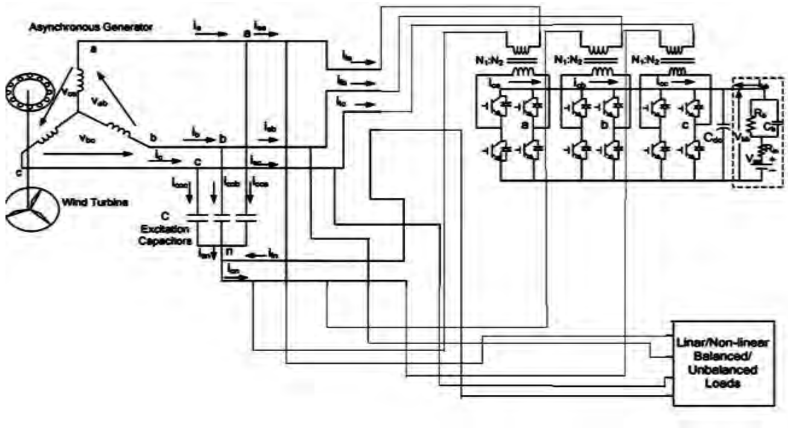

Fig. 4.Three single-phase VSC with BESS-based VFC for a three-phase Four-wire IAG system.

2.2.2. Three-Leg VSC with Midpoint Capacitors as a VFC

This system is made up of a three –phase four wire current controlled voltage source converter through which the neutral terminal for the load is created through the midpoint of a pair of capacitors connected in parallel to the BESS. It sis preferred due to its lower number of power semiconductor devices with regard to the four-leg topology [51].

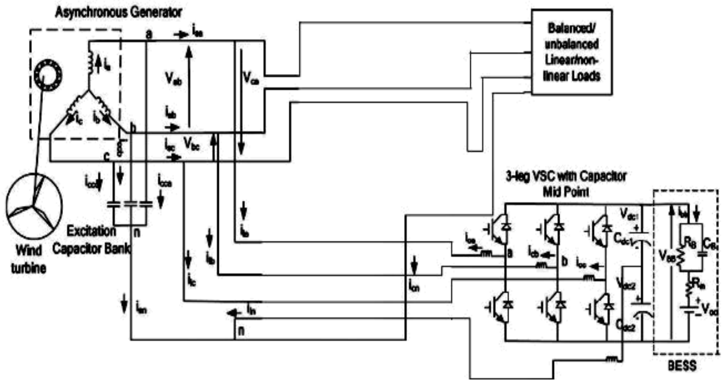

Fig. 5.Three-leg VSC and midpoint capacitor with BESS-based VFC for three phase Four-wire IAG system

2.2.3 Four-Leg VSC as a VFC:

The excitation capacitor is in star form along with neutral terminal used for generating rated voltage at no load. The neutral terminal of the excitation capacitor bank is connected to the consumer load this is the fourth leg of proposed VFC (shown in fig 6.)

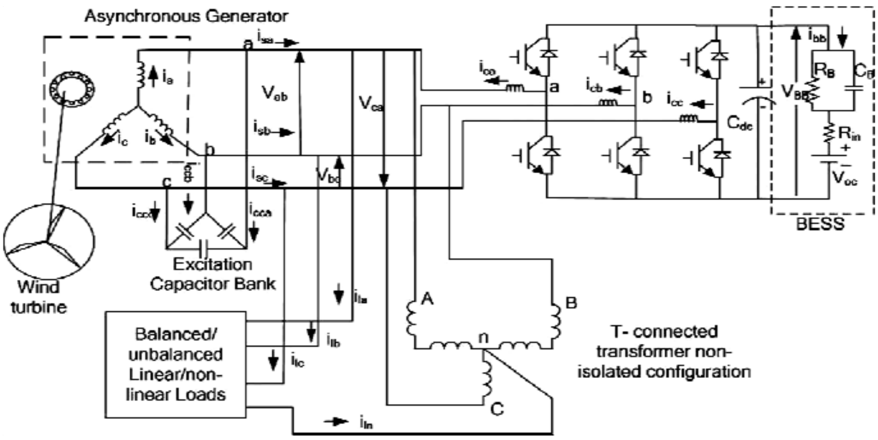

Fig. 6.Four-leg VSC and BESS-based VFC for a three-phase four- wire IAG system

2.2.4 Three-Leg VSC with a T-Connected Transformer as a Controller:

The fig 7 and fig 8 shows the VFCs with three leg IGBTS based VSCs and a battery at its dc bus with non-isolated and isolated T-connected transformer configurations for standalone WCES with IAG [31].The neutral terminal is created through T-connected transformer for consumer load. shown in fig 7 and 8 These transformers act as a path for a zero-sequence component of load currents while VSC along with the battery serves the purpose of harmonic elimination, load balancing, load levelling,

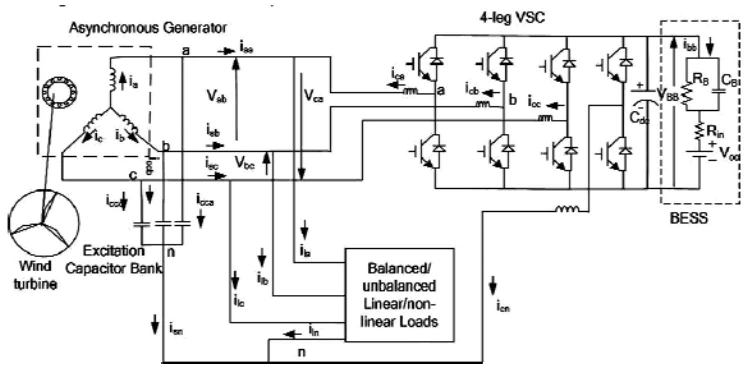

Fig-7 Three-leg VSC and non-isolated T-connected transformer with BESS-based VFC for a three-phase four-wire IAG system.

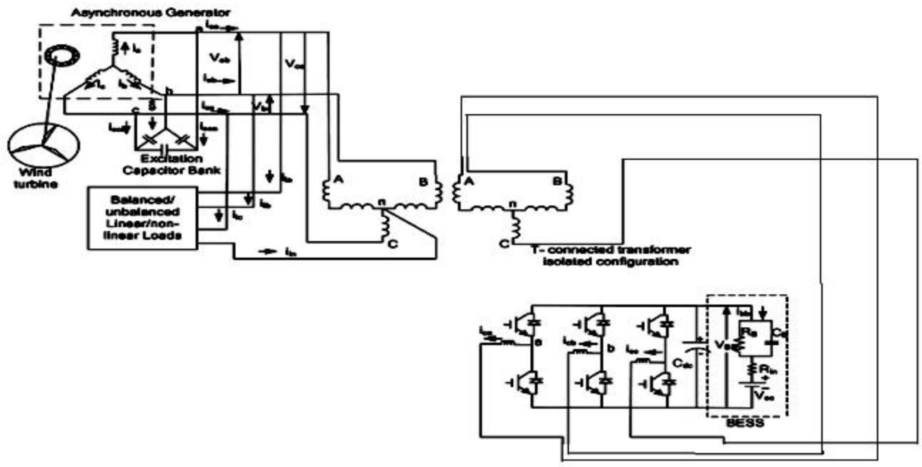

Fig -8 Three-leg VSC and an isolated T-connected transformer with BESS-based VFC for a three-phase four-wire IAG system.

3. Conclusions

An extensive review of voltage frequency controller has been presented to provide a clear perspective on various aspects of the VFCs to the researchers and engineers working in this field .A new VFCs have been presented here for an isolated wind power generation system employing an isolated asynchronous generator .The values of the AC inductor , DC link capacitor, DC link Voltage , and battery parameters have been computed and their values can be selected on the basis of their performance , availability of the component and according to the safety factors. For the three-wire WECS, three leg VSC with BESS –based VFCs is preferred to control a three-phase three-wire IAG system because of reasonably good performance and low cost. and in the case of four- wire WECS, four-leg VSCS with BESS based VFC is preferred for a three-phase four-wire IAG system because of small size , reduced cost. Also an isolated zig-zag/star transformer and three-leg VSC with BESS-based VFC are preferred for four-wire IAG system facilitating an optimum battery voltage and reduced size of VSC.

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