REVIEW ON VOLTAGE REGULATION TECHNIQUES OF SELF EXCITED INDUCTION GENERATOR

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Abstract— Self-excited induction generators (SEIGs) are in-creasingly being used in small-capacity isolated applications for harnessing both conventional and renewable energy resources. These SEIGs suffer from poor voltage regulation even when driven by constant speed prime movers or fixed head hydro turbines. The suitability of these SEIGs to regulate the terminal voltage is a key factor in deciding its use in various applications. This paper deals with the voltage-regulating (VR) schemes for SEIGs, which are found scattered in the literature, and summarizes their operational aspects and relative suitability. These VR schemes are classified on the basis of shunt and series compensation as classical schemes.

I. INTRODUCTION

The increasing concern for the environment and resources has motivated the world towards rationalizing the use of conventional energy resources and exploring the non-conventional energy sources to meet the ever-increasing energy demand. A number of renewable energy sources micro hydro, wind, solar, industrial waste, geothermal, etc. were studied. Science small hydro and wind energy source are available in plenty, their utilization was felt quite promising to accomplish the future energy requirement [1].Traditionally, synchronous generator have been used for power generation but induction generator are increasingly being used these days because of their relative advantageous features [2]. Self-excited induction generators (SEIGs) are increasing being used in small-capacity isolated applications for harnessing both conventional and renewable energy resources. These SEIGs suffer from poor voltage regulation even when driven by constant speed prime movers or fixed head hydro turbines. The suitability of these SEIGs to regulate the terminal voltage is a key factor in deciding its use in various applications. This paper deals with the voltage-regulating (VR) schemes for SEIGs, which are found scattered in the literature, and summarizes theiroperational aspects and relative suitability. These VR schemes are classified on the basis of shunt and series compensation.

II. OBJECTIVES

A. **Choice of electric generator:**

Traditionally, synchronous generators have been used for power generation but induction generators are increasingly being used these days because of their relative advantageous features over conventional synchronous generators[3].

- brush less and rugged construction,
- low-cost,
- maintenance and operational simplicity,
- good dynamic response,
- Capability to generate power at varying speed.

The later feature facilitates the induction generator operation in stand-alone/isolated mode to supply far flung and remote areas where extension of grid is not economically viable; in conjunction with the synchronous generator to fulfill the increased local power requirement, and in grid-connected mode to supplement the real power demand of the grid by integrating power from resources located at different sites.

B. **Construction and characteristic of SEIG**

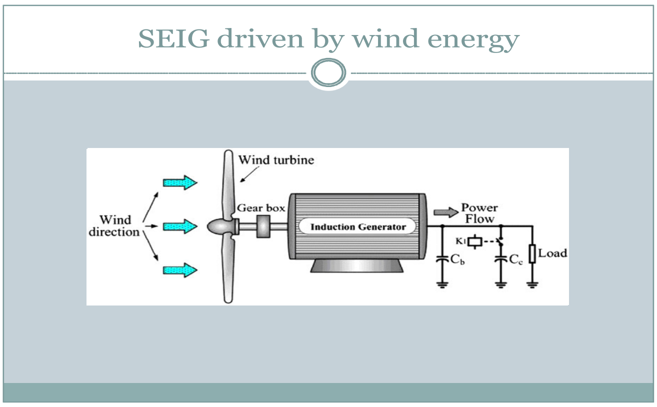

Fig-2.2 [1]

The schematic diagram of SEIG is given below the excitation capacitance required by SEIG is given by following equations[4].

$$\begin{bmatrix} V_{s(abc)} \\ V_{r(abc)} \end{bmatrix} = \left[[R_{s(abc)}][R_{r(abc)}] \right] \cdot \begin{bmatrix} I_{s(abc)} \\ I_{r(abc)} \end{bmatrix} + p \begin{bmatrix} \Lambda_{s(abc)} \\ \Lambda_{r(abc)} \end{bmatrix}$$

$$\begin{bmatrix} \Lambda_{s(abc)} \\ \Lambda_{r(abc)} \end{bmatrix} = \begin{bmatrix} [L_s] & [L_{sr}] \\ [L_{sr}]^T & [L_r] \end{bmatrix} \cdot \begin{bmatrix} I_{s(abc)} \\ I_{r(abc)} \end{bmatrix}$$

The balance of real power can be found by equating the real part of stator branch and real part of rotor branch
The slip can be solved from following equation

$$Re(Y_s) + \frac{\frac{R_r}{s}}{\left(\frac{R_r}{s}\right)^2 + (X_{lr} f_{pu})^2} = 0$$

The airgap voltage at this operating point given by this equation. This can be used to solve Xm. And from that operating frequency can be found

$$Im(Y_s) + \frac{X_{lr} f_{pu}}{\left(\frac{R_r}{s}\right)^2 + (X_{lr} f_{pu})^2} + \frac{1}{X_m f_{pu}} = 0$$

C. **Characteristic of SEIG:**

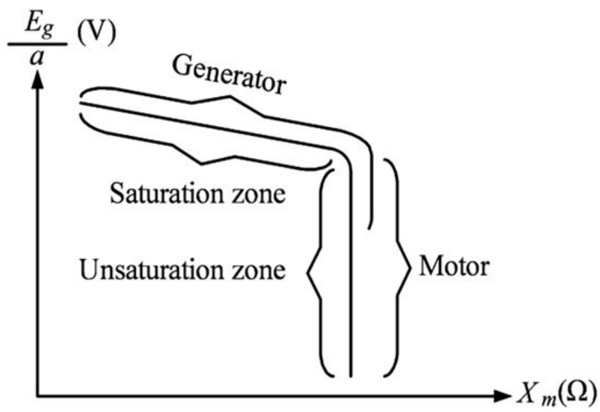

Fig-2.2 [2]

As shown in a three phase induction motor can be made to work as a SEIG when its rotor is driven at suitablespeed by wind energy and its excitation is provided by connecting a three phase capacitor bank at the stator terminal in order to build-up voltage and regulate at a terminal voltage to nominal value. When considering the operation region as shown in Fig which is the relationship between the air-gap voltage and frequency ratio and the magnetizing reluctance, an induction motor operates in an unsaturated (linear) region different from a SEIG operating in two regions namely, both unsaturated (linear) and saturation (nonlinear) regions.
One of the basic requirements of generation planning using induction generator is an effective and comprehensive voltage regulation scheme. In spite of SEIG having a number of advantages, it suffers from inherent poor voltage regulation due to the difference between the VARs supplied by the shunt capacitors and the VARs required by the load and machine.

III. VOLTAGE REGULATION TECHNIQUES

A. **Different types of load connected with SEIG**

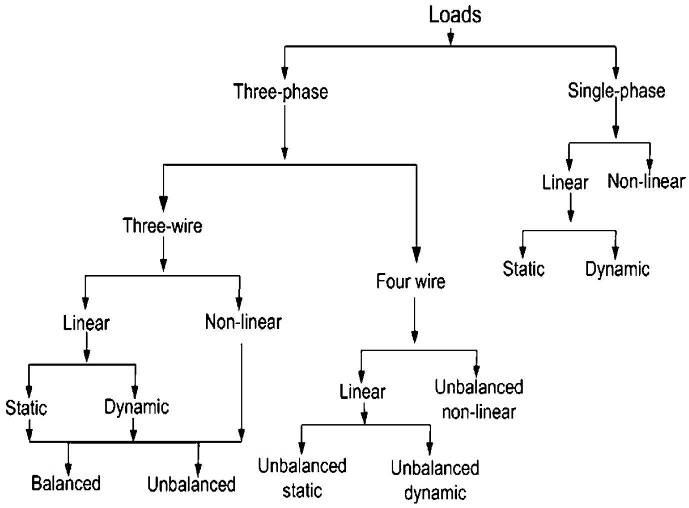

Fig 3.1 [1]

B. **Different** voltage regulating schemes:

(1) Shunt Compensation:
- Classical method
- Switching device base

(2) Series Compensation:
- Classical
- Switching device based

1. **Shunt Compensation**

The voltage regulation in these VR schemes is achieved by the reactive power compensation provided by these compensator.

- Classical Shunt-Compensation-Based: VR Schemes*:* The classical compensation schemes are advantageous due to their operational simplicity and no problems like harmonics and transients.

VR scheme based on a synchronous condenser: An overexcited synchronous machine is connected across the SEIG terminals, which supplies additional VARs during inductive loading to keep the load voltage constant. This scheme is simple and effective in providing the voltage regulation, but it requires a high initial investment and results into large size and high cost.

VR scheme based on a saturable core reactor: The VR scheme based on a saturable core reactor is shown in Fig.. The shunt capacitor bank supplies the VAR requirement of the generator and a pure inductive load and the saturable core reactor absorbs the capacitive current under no load condition.

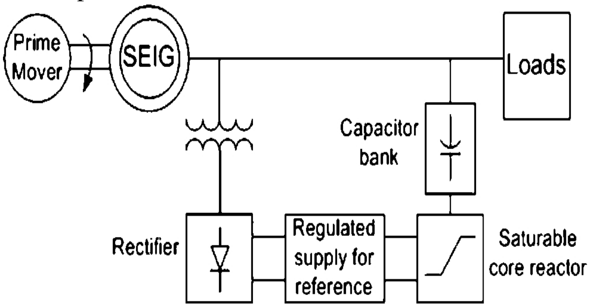

Fig 3.2 [1]

The terminal voltage reduces with the increase in the load, causing desaturation of the core. With the desaturation of the core, the effective inductance increases, thus resulting in a de-crease in the reactor current. Therefore, the capacitor current is transferred to the SEIG, which results in an increased excitation and a higher terminal voltage.[7]

- Switching-Device-Based Shunt Compensation VR Schemes:

VR scheme based on a solid-state switched controlled inductor: A schematic of the VR scheme employing solid-state switched controlled inductor is shown in Fig. A permanently connected capacitor bank Cmin is selected to obtain the rated voltage at no load. After the voltage buildup, the programmable logic controller closes the contact K1 and set the firing angle (α) of the static switch (S) by comparing the sensed terminal voltage (Vt) with the reference voltage (Vref). A capacitor connected through K1 provides the capacitive VAR when the SEIG is supplying the full load. The additional capacitive VARs are absorbed by the inductor connected through a static switch (S)-controlled inductor, which results in a constant terminal voltage [6]

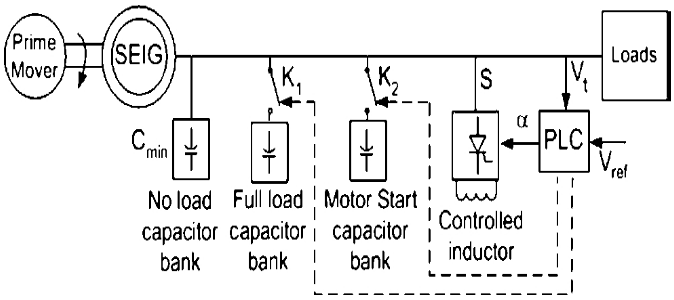

Fig 3.2 [2]

- VR scheme based on switched shunt capacitors*:* Fig. shows a schematic of a VR scheme based on switched shunt capacitors. The capacitance is varied from a minimum Cmin to a maximum Cmax. Cmin and Cmax are capacitances needed to obtain the rated voltage at no load and at a lagging power factor full load. [10]

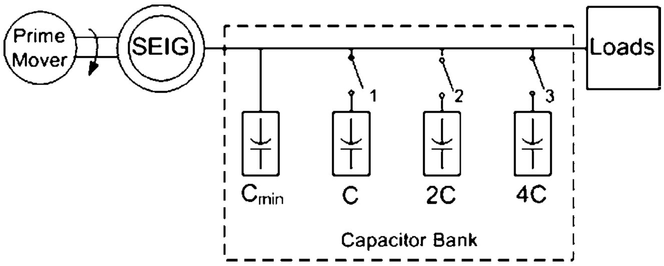

Fig 3.2 [3]

- VR scheme based on controlled shunt capacitors*:* A VR scheme employing continuously controlled shunt capacitance is shown in Fig.. The effective capacitance is adjusted periodically by controlling the on/off control of the self-commutating switching device namely gate turn off (GTO) switch.[10]

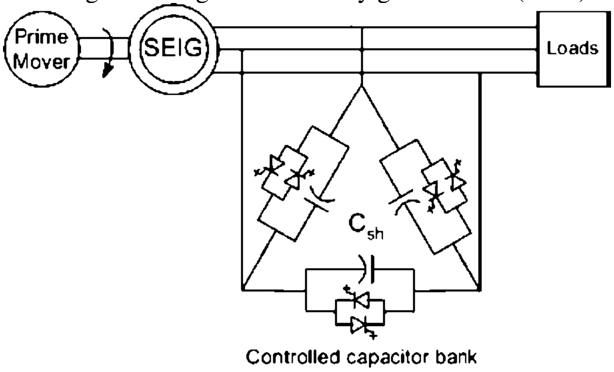

Fig 3.2 [4]

2 **Series Compensation**

The improved voltage regulation of the SEIG is achieved through the series compensation by inserting a source of the reactive power or a passive reactive element. As the load is increased on the SEIG, the additional reactive power is injected into the lines.

- VR scheme based on a CVT: In this scheme, the CVT is connected between the SEIG and the load. The shunt capacitance is selected to provide the rated voltage at the full load. At light load, the excess VARs are absorbed by the CVT while operating in the deep saturation region. This VR scheme results in fair voltage regulation but causes additional losses.[8]

- Series-compensated SEIG configurations: Two configurations of series-compensated SEIGs, namely, a short-shunt SEIG and a long-shunt SEIG, are possible and are shown in Figs With suitable series and shunt capacitances, it is possible to obtain almost flat load voltage profile in both the configurations.[9]

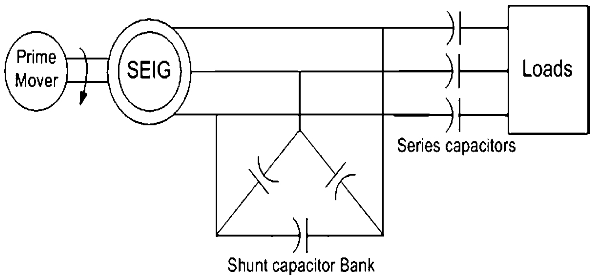

Fig-3.2 [5]

IV. CONCLUSION

As the SEIG have so many advantages its voltage regulation is poor so to improve the VR one of the above method can be used.This paper presents a review on methods of voltage regulation for SEIG.

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