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Study of Current Control of Self-excited Induction Generator using Hybrid Active Filter

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***Abstract* - This paper presents the current control of self-excited induction generator(SEIG).The self excited induction generator is an isolated power source whose terminal voltage and frequency are controlling by the excitation capacitance or the load impedance this is calculating the minimum excitation capacitance using the equivalent circuit for analyze the steady state operation of self-excited induction generator. A new method based on hybrid active filter for controlling the current and power quality of the self excited induction generator.**

The Hybrid active power filter was implemented using a shunt active power filter and connected to the wind generator and loads in order to compensate the current harmonics and reactive power. A hybrid filter which is a combination of series active filter and shunt passive filter. Among the various available combinations, active-passive combination is effective as it has the advantages of both active and passive filters. The characteristics of the passive filter are improved avoiding the problems of series and parallel resonances. The series APF with a shunt connected passive filter is widely used due to the above advantages. Thus, the control of series APF with shunt connected passive filter is studied and analyzed the current control. This paper presents a new control strategy based on hybrid active power filter for controlling the current of self-excited induction generator when generator is connected to a nonlinear load. This paper also represents the analysis and modeling of dynamic model of SEIG. Basically a strategy based on an active power filter (APF) for controlling the current and power quality of the self-excited induction generator (SEIG) has been presented in this paper.

Keywords: Hybrid active power filter, Self excited induction generator(SEIG),Wind energy.

I. INTRODUCTION

The Self-Excited Induction Generator (SEIG) has emerged as the best electromechanical energy converter to replace the conventional synchronous generator in isolated power generators driven by renewable energy resources: biogas, micro-hydroelectric, wind etc. The main advantages of the SEIG are: low cost, ruggedness, absence of a separate DC source for excitation brushless rotor construction (squirrel cage construction) and ease of maintenance. The fundamental problem with using the SEIG was its inability to control the terminal voltage and frequency under varying load conditions. Active Power Filters (APF) are often used in applications where low current harmonics are desirable and/or improvement of quality of energy taken from the power grid are needed. With the use of APF, it is possible to draw near perfect sinusoidal currents and voltages from the grid or renewable distributed power sources. Moreover, it will be possible to balance load currents in different phases which itself is important in stand-alone power generation like wind turbines as for the case of unsymmetrical load currents, it could lead to torque pulsation in generator's shaft and a decrease of reliability. With the use of APF it is also possible to control reactive power and keep unity power factor that is why they are mainly used in industry where DC current is needed e.g. aluminum plants, train power substations, arc welders. The currents taken by household and office consumers have usually high harmonic contents which is related to an increased number of non-linear loads such as rectifiers and capacitors, where the current is drawn at the peak of sinusoidal voltage. At last, it can be said the APF could be used to prevent any kind of harmonic generation (computer's power supply, energy savings lamp, etc.), to reduce: harmonic contents in the grid, peak value of the current drawn from the grid, the inrush current taken from the grid, and to compensate the neutral line current, and correct the active power factor correction, and thus transformers will not be necessary.

II. SYSTEM DESCRIPTION

The basic system diagram are shown in fig.1. It consists of a three phase star-connected induction generator driven by an uncontrolled micro hydroelectric turbine. The generator is operated as an SEIG by connecting a fixed terminal capacitor of such a values as to result in rated terminal voltage at full load. When SEIG supplies a

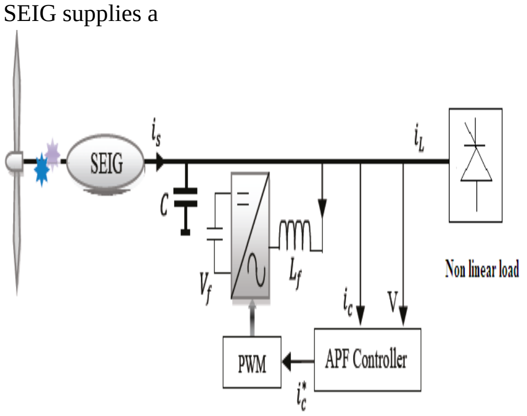

Fig.1. Block diagram of the APF with SEIG

non-linear load, the load draws a fundamental component of current and harmonic current from the generation systems, which are to be properly controlled. The Hybrid APF can compensate the harmonic current by continuously tracking the changes in harmonic content. APF's consists of a voltage fed converter with a PWM current controller and an active filter controller that realizes an almost instantaneous control algorithm shown in Fig.1. As the input power is nearly constant, the output power of the SEIG must be held constant at all consumer loads. Any decrease in load may accelerate the machine and raise the voltage and frequency levels to prohibitively high values, resulting in large stresses on other connected loads.

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III. MODELING OF THE SEIG

The dynamic model of the three phase squirrel cage induction generator is developed by using a stationary d-q axes references frame and relevant volt ampere equations are as follows:

$[V] = [R][I] + [L]p[I] + \omega_r[G][I]$ (1)

Thus ,the current derivative can be expressed as:

$P[I] = [L]^{-1}\{[V] – [R][I] – \omega_r[G][I]\}$ (2)

The SEIG operates in the saturation region and its magnetization characteristics are non-linear in nature. Thus the magnetizing current should be calculated at every step of integration in terms of stator and rotor currents as in:

$I_m = \text{sqrt} (I_{ds} + I_{dr})^2 + (I_{qs} + I_{qr})^2$ (3)

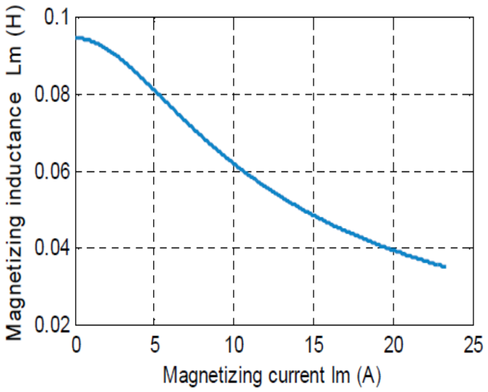

Fig.2. Variation of magnetizing inductance as a function of magnetizing current

Magnetizing inductance is calculated from the magnetization characteristics plotted as L_m against I_m , as shown in Fig.2 for the machine under test. The relation between L_m and I_m is obtained by synchronous speed test.

The developed electromagnetic torque of the SEIG is:

$T_e = (3P / 4) L_m (I_{ds} I_{qr})$ (4)

The torque balance equation is:

$T_{shaft} = T_e + J (2 / P) p\omega_r$ (5)

The derivative of the rotor speed from (4) is:

$p\omega_r = (2 / P)(T_{shaft} – T_e) / J$ (6)

IV. Process of self-excitation

SEIG System Performance

The performance distinctiveness of the SEIG system depend mainly on the following:

- Parameters of induction machine: The machine operating voltage, rated power, power factor, rotor speed and operating temperature and the induction machine parameters directly affect the performance of the SEIG system.
- The Self-excitation process: The connection of a capacitor bank across the induction machine stator terminals is necessary in the case of standalone operation of the system and the use of fixed or controlled self-excitation capacitors have a direct impact on the performance of a SEIG system.
- Load parameters: The power factor, starting/maximum torque and current, generated harmonics and load type also affect the performance of the SEIG system directly
- Type of prime mover: performance of the SEIG system is affected primary source i.e. hydro, wind biomass etc.

V. ANALYSIS AND MODELLING

The basic circuit diagram of this system are shown in fig.3. The the active power filter connected in PCC can eliminate harmonics and reactive current from the load current and make load current sinusoidal.

The three phase instantaneous source current is:

$i_s(t) = i_L(t) – i_c(t)$ (7)

The instaneous source voltage is:

$V_s(t) = V_m\sin\omega t$ (8)

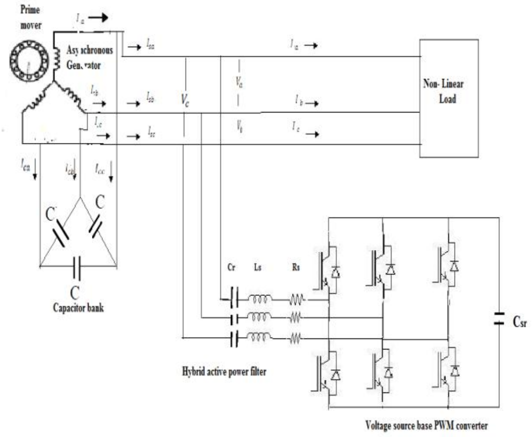

Fig.3. Circuit Diagram of SEIG with HAPF.

If a nonlinear load is applied then the load current will have a fundamental component and harmonic components, which can be written as

$i_L(t) = a_0 + \sum_{n=1}^{\infty} I_n\sin(n\omega t + \varphi_n) = I_1\sin(\omega t + \varphi_1) + (\sum_{n=2}^{\infty} I_n\sin(n\omega t + \varphi_n))$ (9)

VI. PARAMETER OF THE INDUCTION GENERATOR

Table 1.

Line to Line rms Voltage	415V
Line Frequency	50Hz
Diode Rectifier Rating	30KW
R_s	0.1ohm
Ls	0.1mH
DC Link Capacitor	3000µF
Filter Capacitor	3000µF
Filter Inductor	15mH
DC Link Voltage	700V
AC Line inductor	10mH

VII. RESULTS

The proposed control strategy is performance of the control strategy in improving the system behavior. The method is carried under two different load conditions-

i) Non-linear Balanced Load
ii) Non-linear Unbalanced Load

The method is developed to model the control strategy based on p-q theory for controlling the current of a Self-Excited Induction Generator. The complete system mainly consists a SEIG and a hybrid active power filter to compensate the harmonic current and a nonlinear load.

VIII. CONCLUSION

My first objective is to investigate the dynamic performance of SEIG at different transient condition. From the above discussion we can conclude that Voltage developed depends upon

i) Value of capacitor,
ii) Speed of the rotor.
iii) Value of Excitation Capacitance,
iv) Load connected

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The main objective of this work is proposed a method to control current by compensating harmonics of load current. From the active power filter connected in PCC can eliminate harmonics and reactive current from the load current and make load current sinusoidal.

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