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풍력 유도발전기의 여자 축전지에 따른 고주파 증폭에 관한 기술 동향

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Technical Trend on Excitation Capacitors on Harmonic Amplification of Wind Induction Generator

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Abstract - This paper introduce the electrical quantities of a three-phase-connected wind induction generator (WIG) under sudden connection of static loads. An intelligent power-system recorder/monitor is employed to measure threephase voltages and currents of the studied system at WIG's terminals and load's terminals for 5 minutes. A laboratory 300 W wound-rotor induction machine driven by a blushless DC motor is utilized as the studied WIG. Since the generated harmonic currents are randomly varied, total harmonic distortion (THD) of current using cumulative probability density function is employed to determine the penetration of harmonic distortion. The results show that the harmonic currents generated by the studied WIG may be severely amplified to a high level by the connected self-excited capacitance at the stator's terminals.

1. Introduction

According to available references on power quality of induction generators or wind generators, current harmonics and transient currents during grid connection of two 225 kW wind induction generator with pitch control were examined [1]. The prediction of synchronous and asynchronous harmonics generated by induction generators using timedomain measurement was proposed [2]. Transient and harmonics of a GCIG driven by a wave-energy turbine were investigated [3]. Harmonic components in overvoltage waveform and post-fault conditions of both induction generator and synchronous generator were studied [4]. Ferroresonance of dispersed system generation (DSG) using induction generator connected to a small distribution system under islanding operation was presented [5]. Power, efficiency, and current unbalance of a WIG connected to an unbalanced grid using symmetric components were examined [6]. Other power-quality analyses on wind generators can be referred to[7].

This paper introduc transient results of a wind self-excited induction generator connected to an isolated resistive load using a wound-rotor induction machine with short-circuited rotor-winding terminals. Although simple induction generators with squirrel cage rotors are going out of use in wind energy systems, especially the large ones, the primary reason being such systems have to operate at nearly constant speeds, with great increases in stresses in almost all mechanical and structural components. Due to limitations on both employed machines and power capacity of a research university, this paper can only use a wound-rotor induction machine with short-circuited rotor-winding terminals to act as a cage-rotor induction machine for studying the performance of a wind generator. The value of this paper is to use reduced size apparatuses to perform field measurement in order to identify and validate that the harmonic-current effects are due to the presence of self-excitation capacitance connected at stator's terminals of the studied SEIG.

2. Experimental

The Δ-connected stator windings of the WIG is connected to the load through a Y-connected capacitor bank. The Y-connected rotor windings of the WIG are short-circuited together. Each phase of the capacitor bank is represented by a parallel circuit with an excitation capacitor C and an equivalent discharge resistance R_L. Each phase load impedance is represented by an equivalent series circuit with a resistance Rt and an inductance L_t.

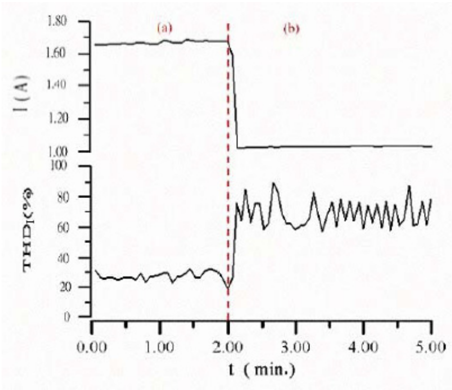
The studied machine driven by a 500 W brushless DC motor has the following specifications: 0.5 hp (300 W), 220 (Δ)/380(Y) V, 1.5(Δ)/0.8(Y) A, 60 Hz, 4 poles, rated speed of 1760 rpm. The excitation capacitor bank is with phase capacitance of 20 μF. When the studied WIG operated as a SEIG, its rotor speed is kept at about 1500 rpm.

3. Results and Discussion

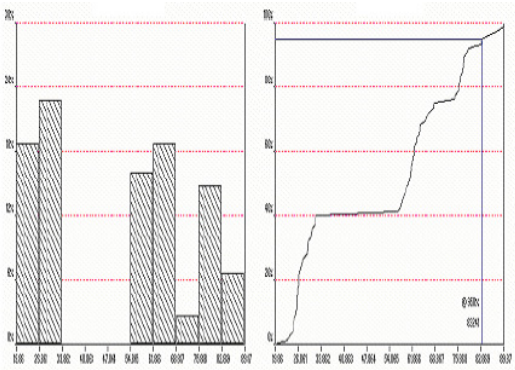
The top plot shown in Fig. 1 (a) is the stator current waveform at WIG's terminals. The bottom plot in Fig. 1 (a) shows the THD variation during the 5 minutes. Before connecting the load, the average value of THD is as low as about 25% average value. However, the value of THD jumps to as high as about 70% average value when the resistive load is connected. The left plot of Fig. 1 (b) shows the probability distribution of THD and it is found the highest probability of 40% is on THD ranging from 19% to 33.8% and the probability of 30% is on THD ranging from 75.8% to 82.8%. The right plot of Fig. 1 (b) shows that the 95% cumulative probability distribution of THD is about 83.241%.

The top plot shown in Fig. 2 (a) is the load-current waveform at load terminals. The bottom plot in Fig. 2 (a) shows the THD variation during the studied 5 minutes. Before connecting the load, the average value of THD is as high as about 400% average value. This no-current section with high THD should be neglected since very low current results in very large and meaningless THD. However, the value of THD drops to as low as about average value of 200% when the load is connected. The left plot of Fig. 2 (b) shows the probability distribution of THD and it is found the highest probability of 50% is on THD ranging from 153% to 246% and the probability of 24% is on THD ranging from 339% to 433%. The right plot of Fig. 2 (b) shows that the 95% cumulative probability distribution of THD is about 496.478%. Since the currents in Figs. 1 and 2 are very small, the obtained values on THD are very high.

Because the three-phase excitation capacitors are located at the terminals just between the WIG and the load, it can be concluded from the measured results shown above that the excitation capacitors contributed severe current harmonics to the load due to their inherent low impedance at high frequency. In other words, the excitation capacitors amplify the high-frequency current harmonics generated from the studied WIG and send them to the connected load.

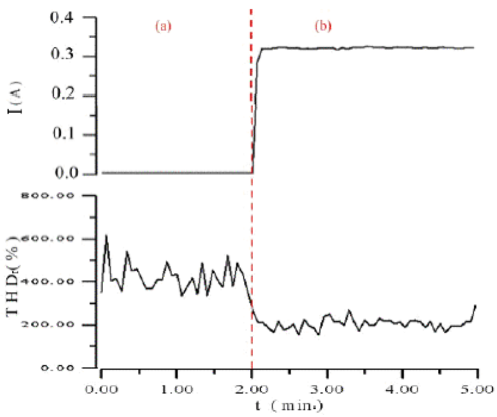


(a) Current and THD

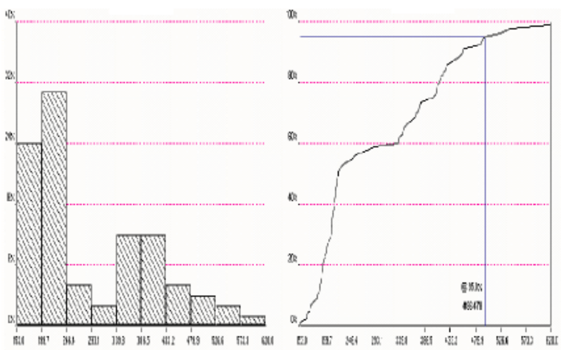


(b) Probability distribution and cumulative distribution function

Fig. 1. Current and THD at the terminals of the studied WIG.



(a) Current and THD



(b) Probability distribution and cumulative distribution function

Fig. 2. Current and THD at the terminals of the studied WIG.

4. Conclusion

This paper has presented the measured electrical quantities of a three-phase Δ-connected wind induction generator (WIG) under sudden connection and disconnection of resistive loads. An intelligent power-system recorder/monitor has been employed to measure three-phase voltages and currents of the studied system at the terminals of the studied WIG and the load. The measured electrical quantities have been analyzed. Total harmonic distortion (THD) of current using cumulative probability density function has been employed to determine the penetration of harmonic distortion at load side. The results show that the harmonic currents generated by the studied WIG can be severely amplified by the connected self-excited capacitance at the stator's terminals.

Acknowledgement

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