AC 2010-898: A MICROPROCESSOR CONTROLLED STATIC COMPENSATOR FOR THE EXCITATION OF AN ISOLATED INDUCTION GENERATOR

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A Microprocessor Controlled Static VAR Compensator for the Excitation of an Isolated Induction Generator

ABSTRACT

A self-excited induction generator offers certain advantages over a conventional synchronous generator as a source of isolated power supply in underdeveloped nations with limited energy resources. However, its practical applications have been restricted because of its inability to control the terminal voltage and the frequency under varying load conditions. In this paper a microprocessor controlled static VAR compensator is proposed and constructed. The self excitation of the generator and the control of the terminal voltage can be obtained using this type of static exciter that can be utilized globally in remote areas.

INTRODUCTION

Induction machines as motors are very common among electrical energy users. The ability of induction machines to operate as generators has been known for a long time. They have been used since the early twentieth century, but they were largely disappeared by the 1960s and 1970s. However, the induction generators had made a comeback since the price of oil began to increase in 1973. With high energy cost, energy recovery has become an important part of the economics of most industrial processes. Induction generators are being utilized in a variety of industrial applications. Due to emphasis on energy conversation, development of suitable isolated power generators driven by unconventional energy sources such as wind has recently assumed greater importance. Brushless rotor (squirrel cage), absence of a separate DC source and ease of operation and maintenance of these type of generators have advantages over the conventional synchronous generators. Difference studies have shown the cost-effectiveness of these machines. Furthermore, they are capable of operating over a wide range of rotor speed well above the synchronous speed, therefore, they have been considered as generators for aircraft, remote hydrostation and wind turbines. They can also be used in a large scale where stable power systems exist or in a smaller scale for cogeneration in remote areas. For instance, such a system does not exist in a wind power supply to isolate communities. However, for an isolated power supply a self-excited induction generator can be a good candidate.

The principle of self excitation is well know[1]. If an appropriate three phase capacitor bank is connected across the terminal of externally driven induction machines, an emf tends to be generated. This phenomenon is known as “capacitor self-excitation”. The induced emf and current in the stator winding will continue to increase until the equilibrium is attained because of the magnetic saturation in the machine. The capacitors provide the magnetizing VAR’s as well as reactive load requirement in case of lagging power factor. In order to reach a steady state generating mode, some permanent magnetism must initially be present in the machine core. The acceptability of these generators depend on their capability to provide desired voltage and frequency at all loads and speeds. However, their practical applications have been restricted because of their inability to control the terminal voltage and frequency under varying load conditions. Different methods of static power convertors facilitate control of output voltage and frequency in self-excited generators[2].

To overcome the voltage variation problem, in this paper a smart static exciter based on a microprocessor controlled reactive compensator is proposed, the proposed technique will utilize a fixed capacitor/fixed filter thyristor controlled reactor (FF/TCR) type of static VAR compensator shown in Figure-1. The branches include a third, a fifth harmonic filter and a TCR. In order to control the terminal voltage of the induction generator during the load or speed change, the value of the excitation capacitor needs to be adjusted. The adjustment of the capacitance can be obtained using the proposed static exciter. With reference to Figure-1, at firing angle zero with respect to the peak of the generator voltage, the thyresistor switch is closed and the inductance cancels the effect of capacitance. By varying the firing angle α between 0^o

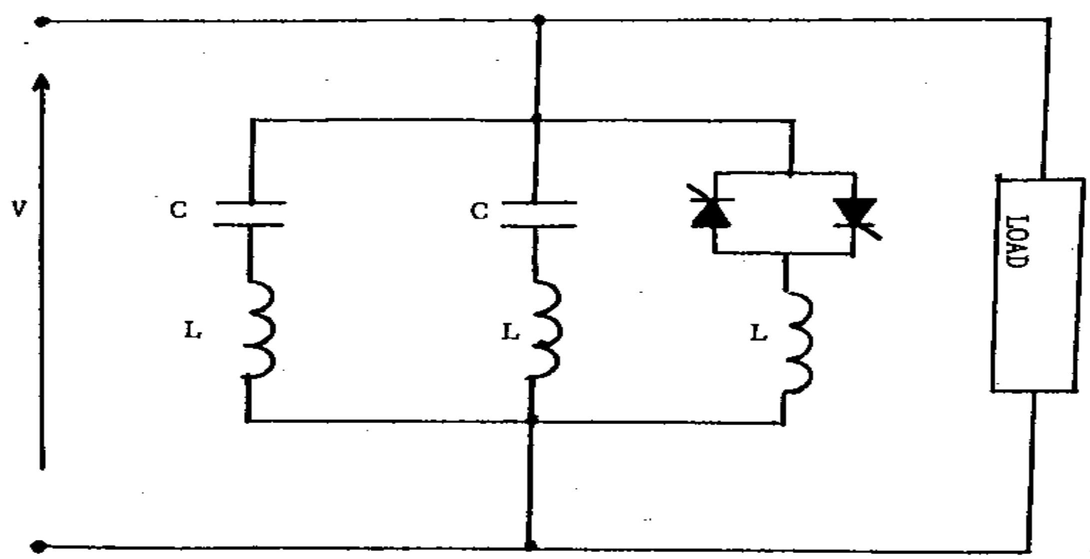

Figure-1. Proposed static exciter

and 90^o, the inductance current decreases and the smooth variation of capacitive current is provided for excitation. Therefore, by varying the firing angle α the value of the capacitance can be controlled. For this type of exciter, variation of capacitance, C, vs the firing angle, α, is known as curve or lookup table[3]. In order to maintain a constant terminal voltage in self-excited induction generator, the required value of capacitance can be obtained using steady state analysis of induction generator[4,5]. This analysis has been carried out for a 400 volts, 12 amp, 60Hz induction genertor[6]. From this study the required capacitance for excitation and maintaining a constant terminal voltage is determined under varying load condition. The results are shown in

Figure-2 and Figure-3. Therefore, the required capacitance values under variable load at different speed and under variable power factor are determined. The control of generator terminal voltage

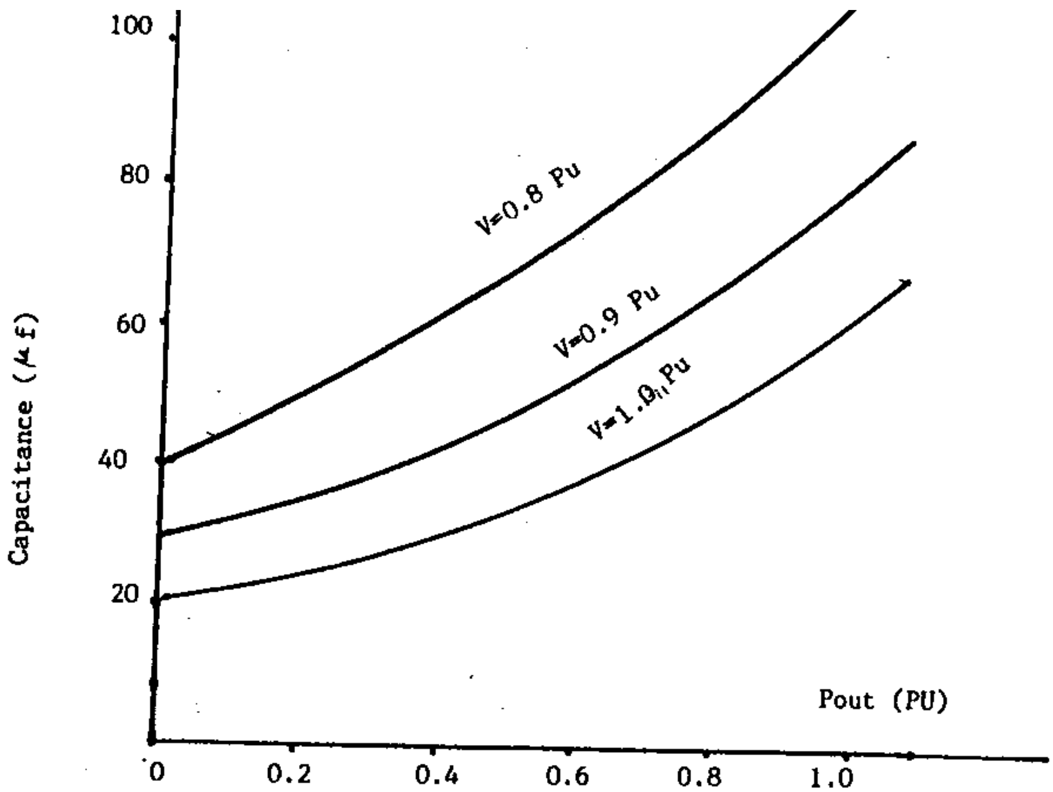

Fig.2 The required capacitance under variable load at different Speeds.

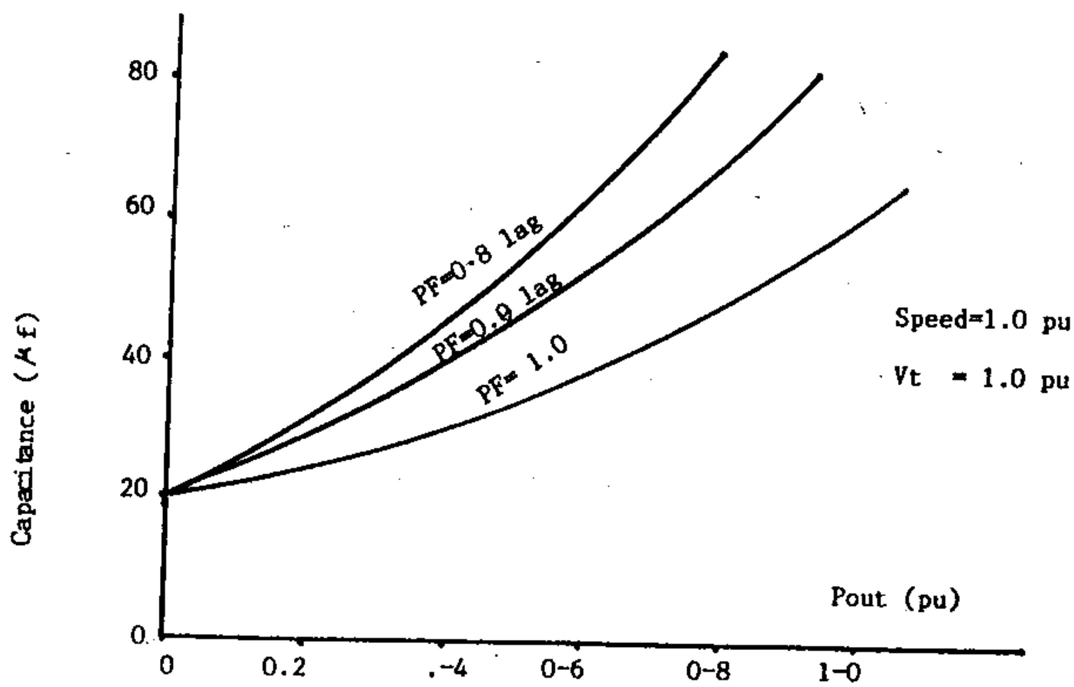

Fig.3 The required capacitance under variable power factors

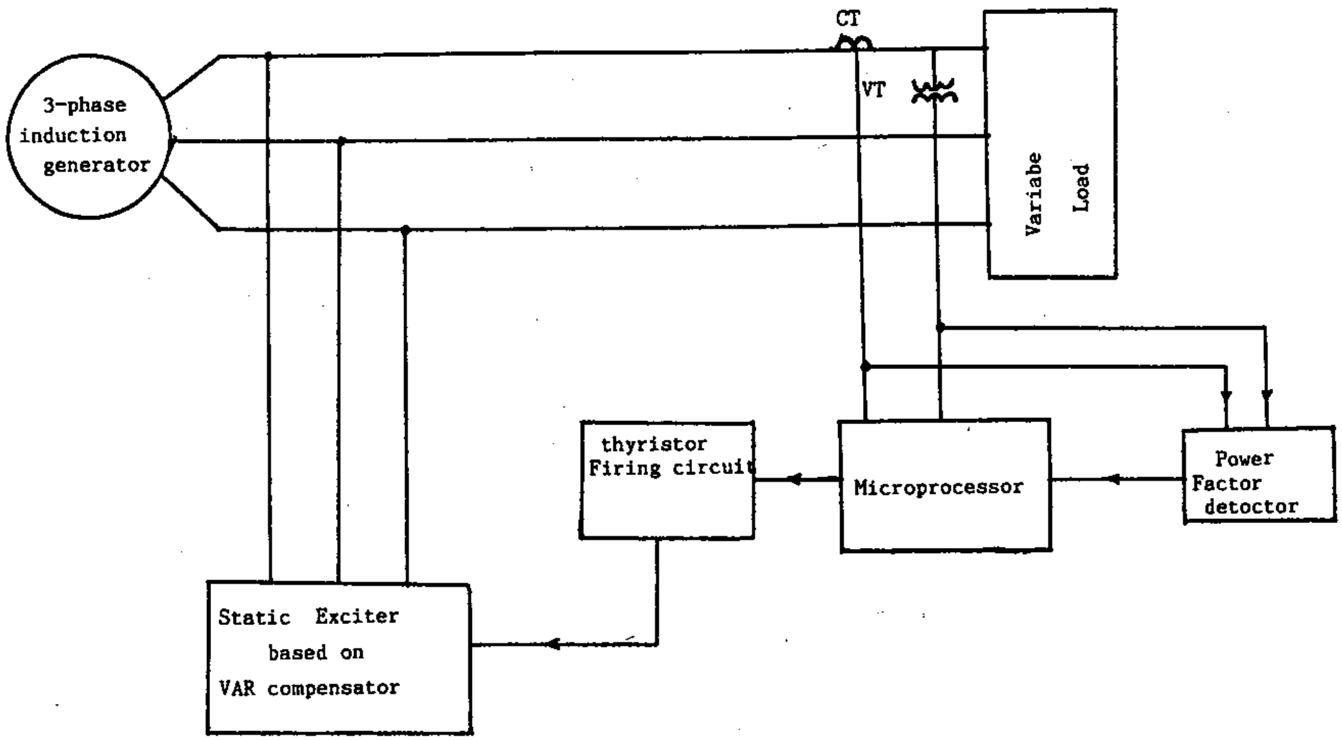

Fig.4 Black diagram of Microprocessor controlled static exciter.

is carried out by a control system incorporating a microprocessor. Based on the values of load and power factor which are determined by the control system, the value of required capacitance is selected from the lookup table. The selected value of capacitance is used to determine the appropriate firing angle from another memory lookup table, then the thyristors are fired at this angle such that the terminal voltage stabilizes at desired value. The block diagram of the control system is shown in Figure-4.

CONCLUSION

The required capacitance to maintain a constant terminal voltage under variable load conditions can be predicted by steady state analysis of a given induction generator. The proposed static exciter is able to provide such variation of capacitance by varying the firing angle in employed thyristor controlled reactor static VAR compensator.

REFERENCES

[1] Barkle, J.E. and Ferguson, R.W. “Induction Generator Theory and Application” Trans. AIEF, 1954, pp 12-19.

[2] Arrillaga, J. and Waatson, D.B., “Static Power /Conversion from Self-excited Induction Generator”, Proc. IEEE, vol 1, No. 125, pp 743-746, 1978.

[3] Miller, T. JE, “Reactive Power Control in Electrical Systems”, John Wiley and Sons, 1982.

[4] Murthy, S., “Studies on the use on Conventional Induction Motors as Self-excited Induction Generators”, IEEE Trans. On Energy Conversion, vol.3, No.4, pp 842-848, 1988.

[5] Tandon, A.K., “Steady State analysis of Capacitor Self-excited Induction Generator”, IEEE Trans. On PAS, Vol. PAS-103, No. 3, pp 612-617, 1984.

[6] Malik, N.H. and Haque, S.H., “Steady State Analysis and Performance of an Isolated Self-excited Induction Generator”, IEEE Trans. On Energy Conversion, Vol.EC-1, No.3, 1986.