Optimal Capacitor For Maximum Output Power Tracking Of Self Excited Induction Generator Using Fuzzy Logic Approach

Mr.M.Senthilkumar

Abstract--This paper aims to determine the optimal capacitors required for maximum output power of a single phase self excited induction generator (SEIG). This paper deals with theoretical, fuzzy logic and practical approach in order to extract the values of optimal capacitor for maximum output power .To find this capacitor value, non-linear equations have to be solved from the equivalent circuit of SEIG. The advantages of using fuzzy logic approach are universal control algorithm, fast converging, accepting of noise and inaccurate signals. At the end of the paper the theoretical and fuzzy logic results are verified with experimental values.

Index terms--**Maximum output power, optimal capacitor, self excited induction generator (SEIG).**

NOMENCLATURE

a,b	Per unit frequency and speed.
C	Excitation capacitance per- phase,F.
f_g	Generated frequency,Hz
f_r	Rated frequency,Hz
N_r,,N_s	Rated and Synchronous speed,rpm
R_1,R_2	Per- phase stator and rotor resistances, respectively, Ω.
R,X	Load resistance and reactance of resistive and inductive loads, respectively.
R_m,X_m	Per phase core loss resistance and magnetizing reactance, respectively, Ω.
V_L,I_L	Load voltage and load current.
X_1,X_2	Per- phase stator and rotor reactances, respectively,Ω.
X_c	Capacitive reactance per phase of the excitation capacitance, Ω.
Z_e	per phase equivalent impedance, Ω.

I. INTRODUCTION

In remote areas the devoid of supply will be electrified by utilizing the renewable energy resources such as wind, solar, biomass, hydro etc,. The most suitable power generation for such remote areas will be operated with self excited induction generator due to its simplicity, robust, cheap, reliable, ruggedness, overload protection, absence of dc, little maintenance etc,.

Excitation of induction generator in standalone mode through capacitance is mandatory to provide the reactive power and to maintain the voltage across the machine. This capacitor value is determined by solving non-linear equations from the equivalent circuit of SEIG.

In literature, different approaches were made for the determination of excitation capacitance [1-6]. Chan has attempted the determination of capacitance value by solving analytical equation[1]. Alolah discussed the performance of single-phase induction generator [2]. Etlamay derived the formula for finding the capacitor value without any numerical iterations [3] and Tandon has explained the steady state analysis of induction generator [4].

Al Jabri derived the capacitance equation for specific cases of purely inductive and purely resistive loads[5]. Chan and Lai has reported the steady state performance of the three phase SEIG supplying single phase load[6] and self regulated self excited single phase induction generator was described by Fukami et al[7]. In all these methods, core loss resistance has not been considered in the equivalent circuit.

This paper deals with obtaining the proper algorithm in order to get the optimal capacitors for obtaining maximum power from the available wind speeds. To carry out this process, fuzzy logic approach is used. The first part of the paper gives the theoretical approach. Second part explains about the fuzzy logic approach. Third part introduces the experimental practise. Finally values obtained from the first two parts are compared with the practically obtained results.

II. THEORETICAL APPROACH

The conventional equivalent circuit of induction machine modified to suit the varying operating frequency as shown in Fig.1. Also the parameters in the circuits are referred to rated frequency. Here Per unit frequency $a=f_q/f_r$ and Per unit speed $b=N_r/N_s$.

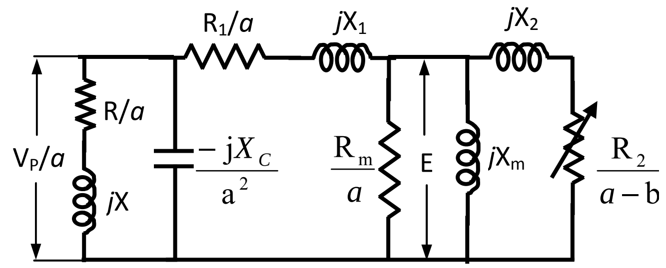

Fig.1. Equivalent circuit of single phase SEIG with load.

From the Fig.1, the loop equation can be written as,

$$IZ=0$$

Where Z is the loop impedance seen by I and is given by,

$$\left\{\left[\frac{R}{a}+jX\right]\|^{el}\left[\frac{-jX_C}{a^2}\right]\right\}+\left\{\frac{R_1}{a}+jX_1\right\}+\left\{jX_m\ \|^{el}\ \frac{R_m}{a}\ \|^{el}\left[\frac{R_2}{a-b}+jX_2\right]\right\}=0 \quad (1)$$

The impedance Z is given as,

$$Z = G_1 + \frac{G_2 G_3}{G_2 + G_3} \quad (2)$$

The expressions of G1,G2 and G3 are given in appendix A

For inductive load, the total current and the total voltage are given by,

$$V = \left[\left(\frac{V_{11}}{V_{12}}\right)^{1/2}\right] aE \quad (3)$$

The expression for V_{11},V_{12} are given in Appendix A,

The output power is given by,

$$P=V^2/ Z. \quad (4)$$

III. FUZZY LOGIC APPROACH

The FLA is applicable to search the generator speed reference which tracks the change in capacitance for maximum output power at varying wind speeds. The FLA(Fuzzy logic approach) block diagram is shown in Fig.2.The FLA doesn't require any detailed mathematical model of the system and its operation is governed simply by a set of rules .The principle of FLA is to perturb the generator reference speed and to estimate the corresponding change in capacitance for the maximum output power. The FLC is efficient to track the optimal capacitance value for the maximum output power, especially in case of frequently changing wind conditions.

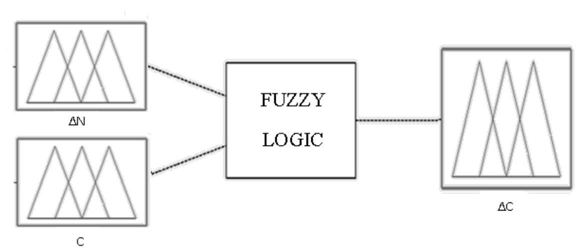

Fig.2 Block diagram of fuzzy logic Approach

Here, capacitor and wind speed are consider as input and change in capacitor as output to track the maximum power. Fig.3 shows the triangular membership functions for fuzzy computation, which gives more accuracy.

Linguistic labels are assigned to each membership functions. The input signals are fuzzified and expressed in fuzzy sets. Using set of rules, the output is obtained. This output is defuzzified to produce the final output.

Fig .3(a), 3(b) and 3(c) shows the input and output membership functions and Table I lists the fuzzy rule table. The output change in capacitance depends on the variation of the input capacitance and the speed. The linguistic variables of the membership functions are given as follows: EL(Extreme Low), VL(Very Low),L(Low), M(Medium), N(Normal), A(Absolute), H(High), VH(Very High), EH(Extreme High).

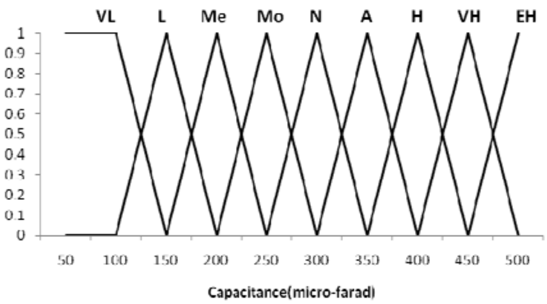

Fig 3(a) Membership function for input 1

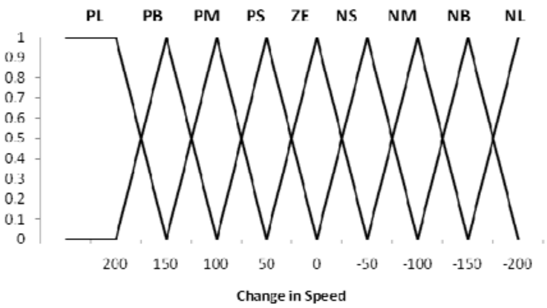

Fig 3(b) Membership function for input 2

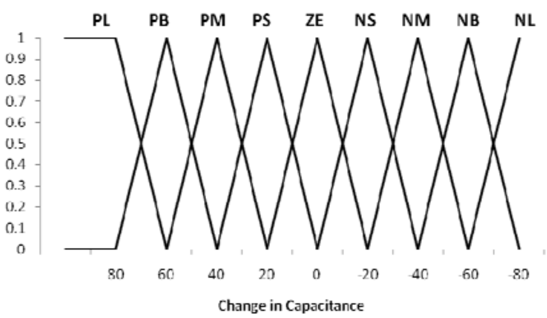

Fig 3(c) Membership function for output

Fig. 4 shows the maximum power tracking curve of self excited induction generator. When the generator runs at the speed of 1600 rpm, maximum power will be at point 'A' for a connected capacitance of 100 micro farad. When the generator speed decreases, the output power will be reduced and the operating point will be shifted to 'B'. In order to obtain the maximum power again, the connected capacitance should be increased to 120 micro farad and hence the operating point will be shifted to 'C'. Similar steps will be followed to track the maximum power. Table II shows the maximum output power for various capacitance values.

TABLE I
RULE TABLE FOR FUZZY APPROACH

ΔN / C	EL	VL	L	M	N	A	H	VH	EH
EL	PL	NS	NS	ZE	PS	PM	PM	PB	PL
VL	PB	ZE	ZE	PS	PS	PM	PM	PM	PB
L	PM	NS	NS	ZE	ZE	PS	PM	PM	PM
M	PS	NM	NS	NS	ZE	PS	PM	PM	PM
N	ZE	NM	NM	NS	ZE	ZE	PS	PS	PS
A	NS	NB	NM	NS	ZE	ZE	PS	PM	PM
H	NM	NB	NM	NM	NS	ZE	ZE	PS	PS
VH	NB	NB	NM	NM	NS	ZE	PS	PS	PS
EH	NL	NB	NM	NS	NS	PS	PM	PB	PL

TABLE II
MAXIMUM OUTPUT POWER FOR DIFFERENT VALUES OF CAPACITANCE

Speed (rpm)	Capacitance (μF)	Power (Watt)
N=1600	40	3236
	80	3533
	90	3635
	100	**3724**
N=1500	40	3109
	80	3430
	100	3598
	120	**3691**
N=1400	40	2923
	80	3164
	120	3435
	140	**3704**

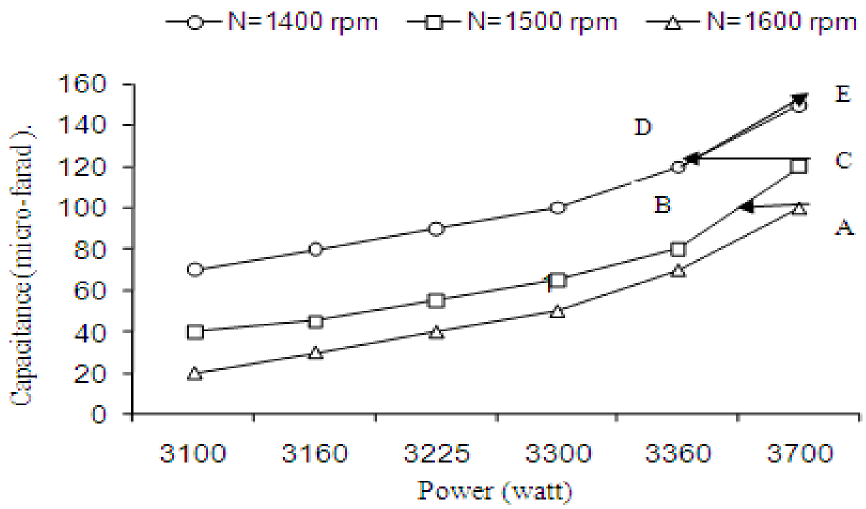

Fig.4 Maximum power tracking curve

IV. EXPERIMENTAL SETUP

The experimental setup includes no load test and blocked rotor test in order to calculate the parameters of Self Excited Induction Generator. For different connected capacitors with different prime mover speeds, the various sets of generated powers have been found with constant resistive load. The rating of this machine is given in Appendix B

V. RESULTS AND DISCUSSION

The results obtained from various approaches such analytical and fuzzy are compared with the experimental results. From the surveillance it is clear that the fuzzy results are more accurate when compared with the other two approaches.

VI. CONCLUSION

In this paper, the optimal capacitors required for the excitation of self excited induction generator are determined using the intelligent tool called fuzzy logic. It is seen that the analysis carried out using fuzzy logic is more accurate in comparison to conventional techniques. The experimental results present close agreement with fuzzy results.

APPENDIX A

From the equation of V,V_{11}, V_{12} are determined as,

$$V_{11} = R^2 + X^2$$

$$V_{12} = ((R_1/a) + R)^2 + (X_1 - X)^2$$

From the equation of Z G_1,G_2,G_3 are determined as,

$$G_1 = \frac{aXX_C - jRX_C}{a^2R + j(a^3X - aX_C)}$$

$$G_2 = \frac{R_1 + jaX_1}{a}$$

$$G_3 = \frac{R_mX_2X_m(b-a) + j\,R_2R_mX_m}{R_2R_m - X_2X_m(a-b) + j[aR_2X_m + R_m(X_2+X_m)(a-b)]}$$

Table III
Parameters of induction generator

Parameters	Value
Stator resistance	1.24[Ω]
Stator reactance	2.58[Ω]
Rotor resistance	1.75[Ω]
Rotor reactance	2.58[Ω]
Magnetising resistance	500[Ω]

APPENDIX B

The electrical details and the parameters of the induction machine are given as follows. The rating of the induction generator is 3.7 KW, three phase,50Hz,415 and 8.1A.

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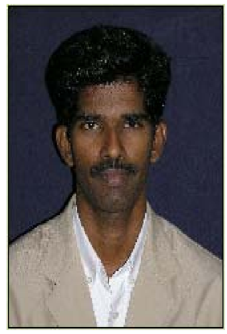
BIOGRAPHIES



M.Senthil kumar finished B.E in electrical and electronics engineering in 1998 and M.E in 2001 from college of engineering, Guindy Anna University.

Currently he is a part time research scholar in National Institute of Technology, Trichy and working as a senior Asst.Prof in Periyar Maniammai University, Thanjavur.