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SUSTAINING PERFORMANCE PROFILE OF SEIG USING OPTIMAL CAPACITANCE INTEGRATION UNDER UNCERTAINTY

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Abstract
If a three phase induction motor having residual magnetism in its core and runs above its rated synchronous speed by mechanical arrangement such as Wind Generator (WG) or Hydro Turbine Generator (HTG) or else steam turbine (ST) can generate electric power, is known as SEIG. SEIG is best alternative for power generation in remote and isolated location in hilly areas as transmission of power to such areas is quite expensive. But Self Excited Induction Generator inherits certain vulnerabilities such as variable output voltage and variable frequency of output voltage and poor profile due to variable speed of Turbine and variable load connected to SEIG. In order to sustain a fixed air gap magnetic field in the vicinity of Induction generator under changing condition of electrical load attached to the Induction Generator and the Under Variable Turbine speed of System, a sufficient and precise variable reactive power source is required which can work in auto controlled mode. The Variable Reactive Power source is achieved by a combination of Inductance and Capacitance. The value of the Inductance and Capacitance must be changeable as per the requirement. In the presented research article, a 1.5 kW SEIG is considered, coupled with variable capacitor bank and variable inductance. The objective of the article is to estimate the optimal value of capacitance and inductance needed to be integrated so as to address variable load and changing primover speed to sustain constant profile of SEIG under uncertainties. A controller is used to achieve the necessity of the Induction Generator Frequency Regulation. The research article proposes a new technique which will supply required reactive power to the stator winding based on Genetic Algorithm. The suggested technique is mathematically modeled and simulated in MATLAB virtual simulation environment and proven to be better than the previously used technique. An honest effort had been made in the article to achieve the expectation of the requirement of standalone Self Excited Induction Generator.

1. INTRODUCTION

The requirement of electrical power is increasing exponentially in the present time, as the consumption of electrical power is mandatory almost every application of human society. The indiscriminate and exponentially increasing exploitations of natural fossil resources for electricity production to fulfill the increasing electrical energy a requirement of the global civilization has brings an issues and anxiety about future of earth [1, 2, 3]. Fossil fuels are empting with a high accelerating speed. In this condition, this is requirement of the time to work in the direction of alternative sources of energy so as to save the environmental condition of the planet and at the same time fulfill the requirement of the society without any adverse effects on the natural resources

A three Phase Induction Motor, attached to an turbine which will rotates prime mover of the motor and operating at a rpm which is more than the rated synchronous rpm of motor, and posses residual magnetic field in the stator and rotor air gap is capable of producing electrical energy in the negative slip zone. Negative slip mean that the machine is working in reverse mode that is motor is working as a electrical energy generator instead of the motion generator. In this condition the mechanical power applied to the rotor of the motor is primary source of power and electrical energy is outcome of the application. In the negative sleep mode the motor start to generates electrical power and is capable to supply power to the load. But the application inherits numbers of terms and condition in order to sustain the negative sleep mode operation of the motor. The most important condition is that the system requires a continuous supply of the changeable reactive power to the output terminal of the motor, otherwise the system will draw the required reactive power from the main grid and if not available that the system will collapse. [5,6]

The above system is known as Self Exited Induction Generator or commonly known as "SEIG", which is generally works in standalone mode at remote location with the application of Wind Generator "WG" or with Hydraulic Turbine "HT". SEIG is an ideal solution for remote location at the places where transmission of power is not feasible and requirement of power is limited. Also the SEIG is robust, efficient and economic which can be operated without any field excitation. Another exciting feature of Self Exited Induction Generator is natural short circuit protection in case of system fault and natural protection against the overloading condition of the application. In case of system overloading condition, the Induction Generator automatically starts to draw extra power from the grid with which this is feeding, although this will adversely effects the application but at the same time this will be in position to address the spike of overloading shocks in operating mode [4, 6].

Design aspects of any renewable energy generator need optimal the election and sizing of it's the paymasters of the component used in the assemble setup. Self Excited Induction Generator appears to be the right candidate to generate an electric power for remote area applications [2]. Self Excited Induction Generator is substantial equipment and this can perform the operation in a self-excited style by the application the supplied mechanical power by the hydro turbine, steam turbine or by a rotating wind turbine. Self Excited Induction Generator is very simple in structure, small, compact in size and weight, high reliable, high efficient, and minimum economical prise in the context of maintenance. Self Excited Induction Generator inherent's protection against short circuit and overloading condition automatically. [8,9]
Wind turbine momentum, injection of the reactive power and the load attached at the output terminal influences the terminal voltage of Self Excited Induction Generator and the frequency

of the generated [9] output power nd voltage. Different schemes such as short shunt arrangement, saturable core reactor and long shunt setup, adjustable shunt capacitor, static voltage compensator that is S_V_C [2, 3] and V or I source arrangement based static compensator are implemented to address poor voltage profile [4]. The presented article also includes different strategies to address the vulnerabilities in comprehensive aspect. In one technique is by the addition a computable capacitor bank and the other one is by application of a SVC setup. In the first method the bank of capacitors is segmented into two portion, one is fixed capacitor bank which is sized to attain the required output voltage level at unload condition, and the second part is one variable capacitor bank as shown in Figure, in which its maximum is required to obtain the documented output voltage at nominal load condition. The second technique is by the application of a Static Voltage Compensator that is SVC. SVC adds a changeable inductor arrangement to a finalizes the capacitor size to attain the required voltage at minimum load condition and another one is variable inductor where this is attained the desired voltage at no-load condition [4].

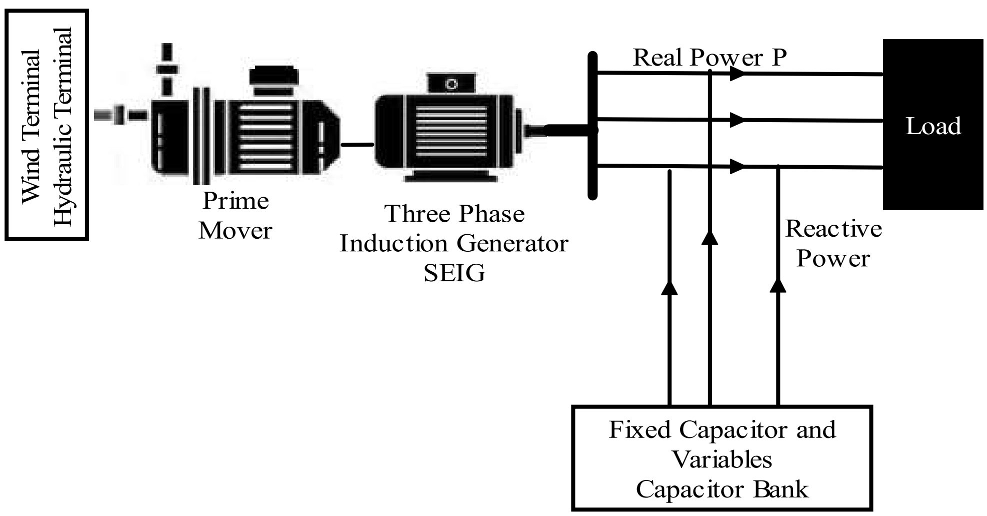

Figure-1. Self Excited Induction Generator – Basic Principal of Working with Fixed and Variable Capacitor Bank

In order for successful building up of the required output terminal voltage there must be residual magnetism present in the core of the generator. This is basic mandatory condition which is needed to fulfill before operation. IN both the cases, that is greet connected mode and isolated mode this condition is a basic requirement for generation of electrical power. Another mandatory condition is that the rpm of the generator must be greater than that of the synchronous speed of the generator. Without this condition there is no possibility for generation of output voltage at all. As soon the generator is start to supply any kind of load, power factor of system will jump out of the range and again the system will fail to generate the power. This condition required a continuous supply of reactive power in the system so that there will be proper excitation, interaction of which will provide the required power at output terminal of the self excited induction generator. When the self excited induction generator is connected with the power system grid, the induction generator will start to observe power from the grid. This condition will ultimately adversely affect the overall grid performance. In this situation this is mandatory that an optimal source of reactive power must be connected at the output terminal of the system, which will supply the required reactive power to the application for efficient working of the application. A combination of capacitors and inductors attachment is ultimate solution for the application at the terminal of induction generator. But the value of the combination of capacitor and inductor must be optimal and exactly meet the requirement of the application. As soon the load varies, the requirement of the reactive power will varies. This means that the arrangement must be self adjusting to meet the requirement accordingly [10,11].

2. LITERATURE SURVEY

L. Yupeng and P Pragasen (2021) suggested the idea of designing thyristor based phase abridged voltage controller for pries effective voltage control at frequency-dependent changing loads for efficient output voltage [1]. A. Al- Manfi and S. Al-moshity (2017) elaborates the concept of synchronous condenser for adjusting for generator's reactive power need for wind power source [14]. M. Parinya, K. Vijit and M Chalermchat (2021) created an algorithm for the counts of the capacitors needed to produces output voltage for the marked loading ratting of a induction generator. Murthy et al., (1993) investigated the capacitance specification of an Induction Generator with the accessory of a unit parallel capacitor for every phase in the system. Bhim et al., investigated approximate analysis of a long-shunt induction generator for series combination and for the shunt capacitors to achieves reactive-power need of the generator. Ojo et al., (1996) clarifies that with the enhancement of a short_shunt along with long_shunt excitation arrangement, the overall performance of Unity phase induction generators could be inhanced.

Wang et al., (1999) proposes that, in case when Self Excited Induction Generator is feeding a fixed load at a constant speed, then in this situation a unit capacitor is best deal for reactive power need of the application. Chan et al., (2002) explain that a practical technique for the calculation of minimum capacitance to startup voltage generation for Self Excited Induction Generator using the repetitive secant method. Houz Wann Seyoum, (2009) said that repetitive excitation and management technique are required because the fluctuation in the output voltage along with frequency [12]. Mohd. Ahmed et al., (2003) suggested the new admittance technique for steady-state frequency-domain investigation for calculating minimum excitation capacitance.

Table 1 presents few important article in the field of self excite induction generator. Authors, name of the research journal and research are explained. The significance importance and utility of the outcome of the research ahd been presented.

Table-1. Noteworthy Research Article in the Filed of Self Excited Induction Genartor

No	Authors and Publication Detail	Outcome of Article
1	"Hayat Aissaoui, Abdelghani in IEEE publication year 2021 transaction regular	"Neural Networks and Fuzzy Logic Based Maximum Power Point Tracking Control for Wind Energy Conversion System" [15] The research article discussed about the basic core

	volume number 6" [15]	principal of operation of the three phase self excited induction generator. Wind Power Turbine is used as input for rotating torque for the prime mover of the generator. Mathematical Modeling is done, mathematical expression is deduced and explain in the detail. The model is simulated in the MATLAB Simulink Virtual Software. The response of the model is tested under different loading condition. Fixed capacitance is calculated using fuzzy logic algorithm and the same capacitance value is taken in the simulation plot of model.
	"Murthy c, Kishore Yadlapati in IEEE Publication in regular transaction in year 2022" [16]	"An Experimental analysis had been done of three phase self excited induction generator. An Ideal test setup is created and the live testing had been done under different loading such and inductive load, capacitive load and resistive load. Response plot had been considered and investigated. Efficiency, losses, performance and stability parameter of the sytem is investigated and analyzed." [18]
	"L. Yupeng and P Pragasen in IEEE Publication year 2021 transaction Volume 10, IECON" [5, 17]	A model is created in the article for self excited induction generator to test the performance under uncertainty. Uncertainty means the variable speed of the turbine due to the catalytic resources such as wind stream or hydro turbine force. The performance is considered under such types of the condition and suggestions are concluded for batter performance and high efficiency under such conditions. Technique are suggested for uncertain condition.

3. MATHEMATICAL MODELING OF COMPLETE ASSEMBLY

As discussed above that a three phase induction motor can as as a power source or electrical power generator if certain mandatory conditions are fulfilled. Most important condition is that the motor must be connected with a optimal value capacitance which can provides reactive power to the stator winding of the induction motor. As soon the load is increases on the terminals which is supplied by this induction generator, the current in the outer circuit try to lag behind voltage and finally the system will collapse. This indicates that a continuous reactive power supplier must be connected and the reactive power provider must be adjustable or in other word this should be auto adjustable as per the need of the reactive power. The power supplied must be optimal, this is a mandatory condition. Three phases self excited generator are small and handy in the size and economical also. This feature makes the SEIG an ideal solution for small power requirement at remote areas and at the hilly areas also. As the transmission og power at the remote location is not fissile in the context of economical aspects. The interdependence of most significant parameters, such as terminal output voltage of the induction generator and output voltage frequency of induction generator on the rpm of the primover, load attached with the induction generator, and field capacitance attached at the terminals at output windings imposes conditions on its usage and limitations of the utilization. An SEIG with a constant magnitude of capacitance attached at the field winding of the system presents complex issues with the applications. As the generating systems requirement are variable which depends upon the load connected to the induction generator. As soon the load is increases the requirement of reactive power increases to maintain the field sustained at required condition so as the system will be able to feed the load. At the other end in case if the load attached with the application decreases the requirement of reactive power by the induction generator is also decrease and if the reactive power source still providing the same amount of the reactive power the generator became unstable and will jump to unstable zone and ultimately collapse.

This discussion signifies the importance of a variable reactance source which must operates in self auto adjustable mode so as to address variable requirement of the reactive power. This is on most importance aspect of self excited induction motor. Unequal reactive power supply will present instability and efficiency of application will also compromise. This fact indicates the importance of auto adjustable reactive power source at field winding of induction generator. The problem can be solved by finding an approximate value of capacitance and an adjustable small value capacitance which will be adjusted at the run time as per the requirement of the system.

This is why, the election of add-on or suitable capacitance value under changing generator rpm as per the turbine attached and variable loads needs artificial intelligence or optimization techniques to address the two documented major limitations of self excited induction generators. For the election of fissile capacitance value knowledge of the performance specification, specification of the operating parameter, system specification, and terminal conditions are required by the optimization algorithm or by inelegant software.

In this context mathematical modeling is mandatory so as to specify the exact value of the required parameter. The next section will develop mathematical equivalent model each and every devices which are attached with the induction generator assemble that is Gear Box and the Primover.

3.1. PRIME MOVER

Exact and pacific mathematical modeling of Induction Generator components will surely extremely to helpful to investigate the system and to develop the control strategies for efficient performance. The analysis of Induction generator is complex and is very difficult to analyze in sample 2 d frame coordinate system. The d-q model technique is reference plane techniques which is generally used to analyze and investigates complex mathematical model which ingrate's different parameter which are interdependent. DQ model technique is stands for Direct Quadrate Technique which uses projections of vector quantities on different plans which are component of that Quantity in that plan. The technique is equally applicable to steady state and transient state modeling and simulation but this is more efficient and exact in the case of the transient analysis of any model. In present case, this is used to forecast the transient response of Self Excited Induction Generator under variable operating conditions and under different state that is steady state and transient state. The application components are a hydro turbine, wind turbine of a steam turbine, a capacitor bank of fixed magnitude for starting phase of the application with a value of 20µF, a switchable assembly capacitors that will be added with a value of 26 µF or else 1.4 H magnitude variable inductor and a loop which will control the reactive power which is likely to be inserted to the stator winding of induction generator [11, 12].

A wind Turbine, Hydro Turbine or a Steam Turbine will extract mechanical power from the source of energy. The amount of Mechanical Power generated will be given by the following equation

$$P_m = \frac{1}{2}\rho SC(\lambda, \quad \beta)\, V_w^3 \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots 1$$

Where

ρ: Density coefficient of Air or Vacuum measured in kg/ meter

S: Swept area of the Turbine of Power Generator measured in (meter)^2

C_p: Turbine Coefficient of the Mechanical Turbine

λ: Ratio of the Tip speed to the Blade of the Rotor

β : Pitch Angle of the Blade of the Turbine in degree

V_w: Speed of Wind speed or else Steam

The rotational speed of the wind or steam turbine Ω which is measured in radian per second) is given by following expression

$$\Omega_t = \frac{(\lambda \,.\, V_w)}{R_t} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots 2$$

Torque Coefficient of the System is ratio of the Performance Coefficient to that of the λ. Integrating the torque coefficient $C_m = \frac{C_P}{\lambda}$ in the above expression than we get the following expression as below:

$$P_m = \frac{1}{2}\rho\pi R^3 C_p(\lambda \quad \beta)\, V_w^3 \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots 3$$

A core expression can be presented for the present model as below

$$C_p(\lambda \quad \beta) = 0.5.\left(\frac{116}{\lambda_i} - 0.4\,\beta - 5\right)e^{-\frac{2l}{\lambda}} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots 4$$

$$\frac{1}{\lambda_i} = \frac{1}{(\lambda + 0.08\beta)} - \frac{0.003}{(1 + \beta^3)}$$

In the above expression-4 the Cp represents the aerodynamic parameter of the prime mover.

3.2. GEAR BOX

The gearbox assembled in the power coupling of induction generator is a mechanical arrangement of unequal number teethed gears which are attached with the turbine and this is capable to transmit torque load from a primary mover that is turbine to a rotary outcome which is concerned to the angular motion along with torque. Gear Box connects the low angular velocity speed shaft and the rotor of the generator that is rotor winding movement is generated by the application of gear box. The ratio is calculated by the requirement of the Self Excited Induction Generator represented by the expression given below in equation 5. Figure 2 depicts the variation of Performance Coefficient "**Cp**" of the Turbine wrt Tip Rotor Speed that is "**λ**" of the rotor of Generator [13].

$$r = \frac{\Omega_t}{\Omega_m} = \frac{C_m}{C_t} \quad \cdots\cdots\cdots\cdots\cdots 5$$

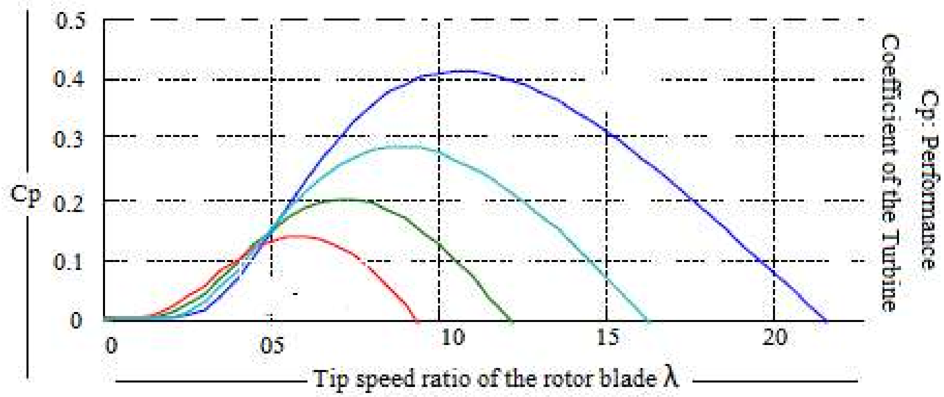

Figure-2. Change in the Coefficient of Performance that is "Cp" of the Turbine with respect to Tip Rotor Speed that is " λ"

4. SELF-EXCITED INDUCTION GENERATOR- ELECTRICAL EQUIVALENT CIRCUIT

A mathematical equivalent circuit of three phase induction generator is displayed in below in next paragraph in figure 3. Two different test that is Blocked Rotor Test and No Load Test is carry out to calculate the parameter of induction generator which is basically an induction motor and likely to be used in the test simulation as SEIG.

The magnitudes of the different parameter and constant are as denoted below along with the notation used in further text.

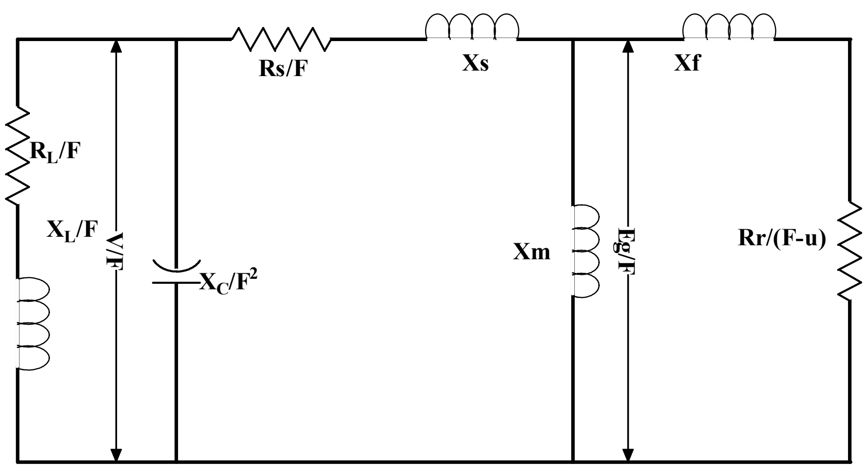

Figure-3. Electrical Equivalent Circuit of Self Excited Induction Generator in Frequency domain

The notations used in the coming expressions are described as below:
R_s = Stator Resistance = 5.15 Ω
l_s = Leakage Resistance = 20.35mH
R_r = Rotor Resistance = 2.24 Ω
l_r = Leakage Inductance = 20.35mH
s = Slip Factor
L_{mn} = Magnetizing Inductance = 0.24 H

The magnetizing Inductance is function of magnetizing current. This can be represented in the below expression as below:

$$L_m = (1.58)^{-11}\, V_s^4 + \, (0.51)^{-8} V_s^3 - \, (0.52)^{-5}\, V_s^2 + (1.08)^{-3}\, V_s^1 + \, 0.24$$

Mathematical Model of Induction Generator is intricate and complicated procedure as the operation contains parameter consideration under transient state also under uncertainty.

In objective to understand the mathematical model, the equivalent circuit had been separated in two imaginary coordinated axis's which is commonly referred as DQ Axis [14]. The DQ reference plan extract two equivalent circuit is depicted in the figure 4.

In the mathematical modeling stator winding and rotor winding are considered mainly. Residual Magnetizing present in the stator core of the induction generator had been also considered.

The analysis is done in the frequency zone domain for simplicity of the mathematical formulation. Leakage is taken in the range of the 20 mH for the air gap in between stator core and rotor winding.

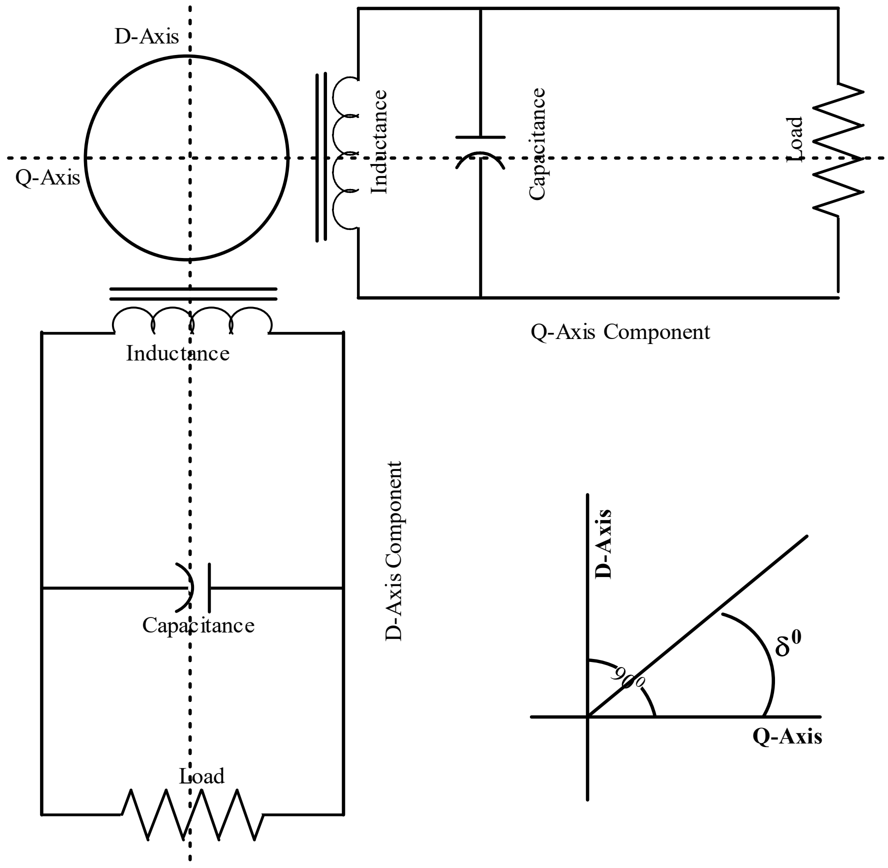

Figure-4. SEIG in d-q axes stationary reference frame

5. VOLTAGE REGULATION OF SEIG

One of the most important parameter which is needed to be considered is voltage regulation of Self Exited induction generator. The terminal voltage of the Self Exited Induction Generator must be remain same irrespective of any variation in the loading condition or else any change in the turbine speed which is feeding to the primover of the Self Exited induction generator.

A fuzzy logic system is utilized to address the issue of voltage regulation for Self Exited induction generator, by operating the switching device connected to variable capacitance and variable inductance which inject the required reactive power to the Self Exited induction generator required to maintain the regulation within the permissible limits, adjusting the varying capacitance magnitude.
Fuzzy logic control is used to activate the switchable capacitor or inductors to fulfill reactive power requirement. Input parameters are as listed below for fuzzy logic controller in below equation.

$$error\ \varepsilon = V_{ref} - V_{dc} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots 6$$

$$\frac{d\epsilon}{dt} = \frac{V_{ref} - V_{dc}}{d_t} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots 7$$

Above expression are utilized to generate the required duty cycle and magnitude to inject the needful reactive power to the stator winding or field winding of the Self Exited induction generator as shown in figure 5.

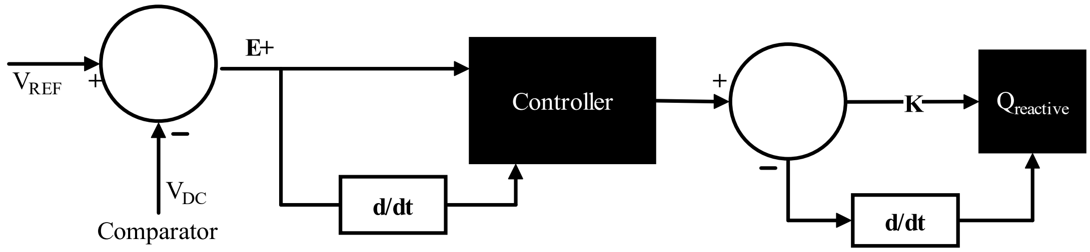

Figure-5. Reactive Power Injection to SEIG

Fuzzy logic controller is sophisticated device which compare two signals and after comparison the controller will trigger a signal to the relay which will take next step to control the magnitude of the quantity. Vref is the reference value which is fixed by the user and Vdc is the output terminal voltage of self excited induction generator. Fuzzy controller will compare these two quantities and initiate a signal for further processing. This is commonly used strategy in most of the signal comparison applications.

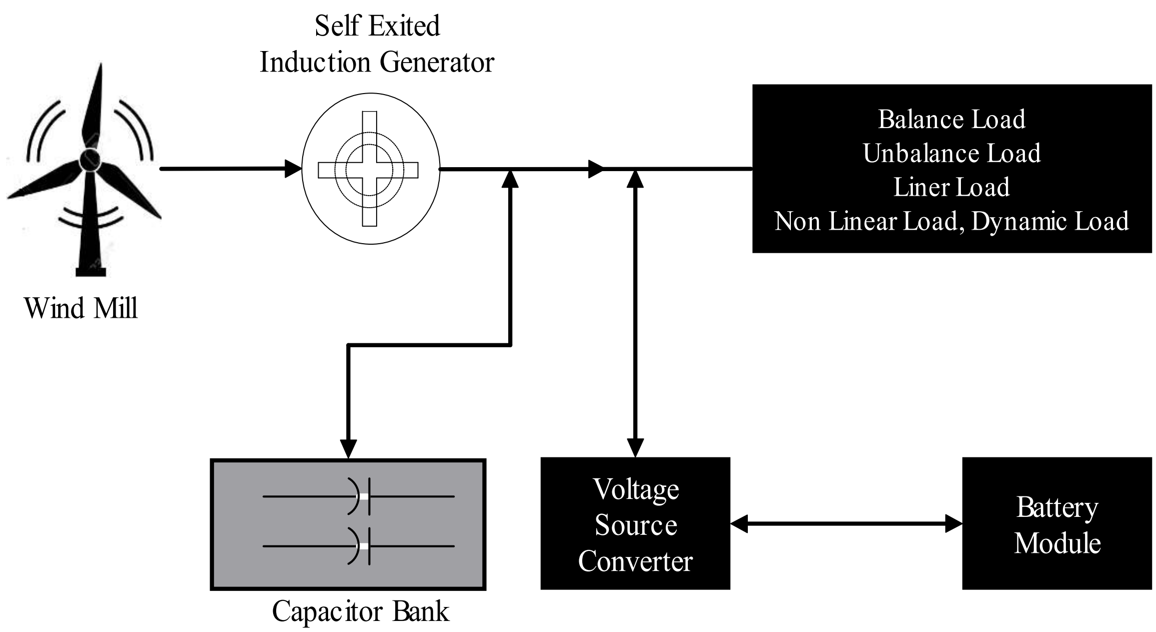

Figure-6. An Strategic presentation of Reactive Power Injection in Induction Generator

5. TEST SIMULATION

Matlab virtual simulation environment had been used for test simulation and hypothesis testing of the suggested model. The simulation model for the suggested capacitance value which is likely to be integrated in filed winding of the self exited induction generator is done in Simulink IDE of Matlab software. A DC motor is had been utilized to rotate the turbine which will rotate the prime mover of the self excited induction generator. As per the specification of the three phase induction generator which will be used as self excited induction generator the synchronous speed is 1500 rpm. Hence the DC Motor mst runes above 1500 rpm. When rotor of self excited induction generator runs at nearly 1500 the frequency of the output termical voltage will be 50 hz.

This value is estimated as the reference frequency of self excited induction generator frequency term for output terminal voltage. The command of the SEIG system is dependent on the AC voltage specifications which are needed by the attached electrical load is nearly equal to 200 V. This value Vref is calculated as a reference value for AC-bus voltage.

The prime concept behind the presented article is to find the optimal value of the capacitor which is needed to be attached at the field windidng of the Induction generator. Priviusley different research scholar had estimated the value pof the optimal capacitance. For theInduction generator which is taken as test machine in the prsenet papare, the optimal capacitance value is 36µF calculated bty traditional Method that is Mathematical Calculation Base. The second value is 43µF which is calculated by Fuzzy Concept Based. In this article Genetic Algorithm is utilized to calculate the value as 38µF. This is to be noted that the value of fixed capacitance must be inbetween 30µF to 45F. There are different conditione will be came if value of fixed capacitance is out of this range. If the capacitor attached is below 20µF than the Seig will Not Built the Voltage, If the Capacitor attached is between 20.1 to 36µF, induction will suffer over heating condition and Terminal Voltage will be Unstable. If the capacitor attached between 36.1µF to 45 µF stable voltage but Efficiency is low and Heat Dissipation is high. If capacitor attached is above 45 µF than Overexcited will be observed and System will collapse.

Table-3. Integrated Capacitor (in 20µF) Range and Response of SEIG

No	Capacitor Specification	Response of SEIG
01	Capacitor Attached Below 20µF	The Seig will Not Built the Voltage
02	Capacitor Attached Between 20.1 to 36µF	Over Heating Terminal Voltage Unstable
03	Capacitor Attached Between 36.1µF to 45 µF	Stable Voltage but Efficiency is low and Heat Dissipation is high
06	Capacitor Attached above 45 µF	Overexcited Extra Heat System Collapse

The test system is formed by a separately excited 1.5 kw DC Motor, which works as turbine which will responsible to rotate the prime mover of induction genartor under consideration. A 1.5 kw SEIG, a 80µF capacitor bank, or else a 1.4H inductor is taken in the test application. The schematic for the test system is as depicted in the figure 7 on the same page. The operator sets the frequency of the voltage and magnitude of the voltage at terminal end [12].

Table-1. Parameter of SEIG

No	Parameter	Notation	Value
1	RatedPower	P_r	1.5 Kw
2	RatedVoltage	V_s	230 V
3	RatedCurrent	I_N	3.4 A
4	RatedSpeed	X_N	157 rad/s
5	Count of Poles	P	4
6	Rotor resistance	R_r	2.24 Ω
7	Stator resistance	R_s	5.51 Ω
8	Stator inductance	L_s	20.35 mH
9	Rotor inductance L_r		20.35 mH

Table-2. DC Motor parameters

No	Parameter	Notation	Value
1	DC supply voltage	V_{DC}	220 V
2	Rated armature current	I_{an}	9 A
3	Rated field supply	F_r	220V/ 0.6 A
4	Rated speed	Ω_N	157 rad/s
5	Armature resistance	R_a	1.4 Ω
6	Armature inductance	L_a	27 mH

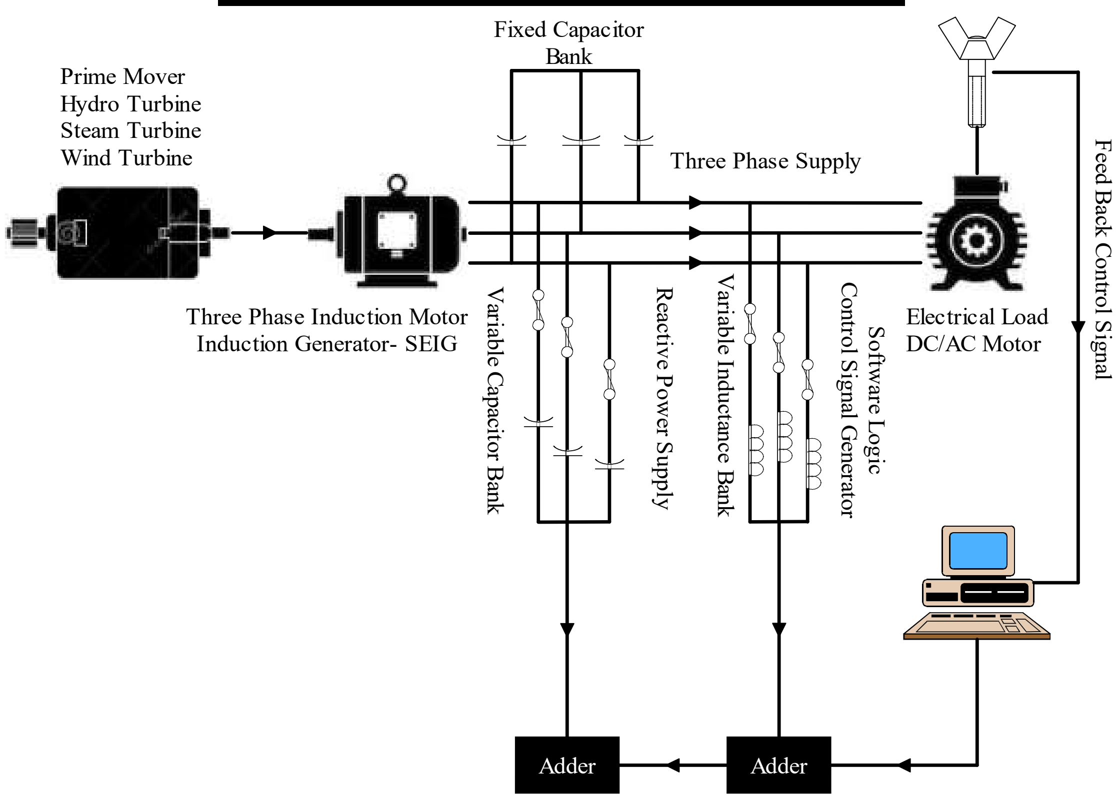

Figure-7. Proposed Experimental Setup for Simulation Response of Self Excited Induction Generator

Table-4. Suggested Value of Integrated Capacitance with different Technique

No	Techniques Used to Find Capacitor to be Integrated	Value of Capacitor
01	Traditional Method (Mathematical Calculation Base)	36µF
02	Fuzzy Logic Based	43µF
03	Genetic Algorithm Based	38µF

The table 4 presents the value of the optimal capacitance which is attached to the field winding of the Induction generator. Two different technique is considered to calculate the fixed capacitor value as shown. The range of value must be within 35 µF to 45 µF.
Traditional Method that is Mathematical Calculation suggest the value of capacitance is 36µF. At the same time the Fuzzy Logic Based calculation suggests 43µF as the value of the fixed value capacitance. This article uses Genetic Algorithm Based value estimation which indicates that 38µF is the value of fixed capacitance. Next paragraph consider the response plot with this value and effect and variation on the terminal voltage under different loading condition and under different system mode, that is initial mode, stable mode, overloading mode and under loading mode. These entire modes are considered and response of the output voltage and system had been plotted. Most important response curve is depicted in the next paragraph.

TERMINAL VOLTAGE REGULATION USING CAPACITOR BANK

When a group of numbers of capacitor are connected together to form a compact unit in order to supply reactive power or virtual power to a system is known as Bank of Capacitor. In electrical engineering capacitor banks are used at numbers of location. When feeding an inductive load, the power factor will adversely affect and the power system will tends towards instability. This will ultimately result in increased losses and poor efficiency and also having negative effects on the equipment connected with the power system.

Traditionally a capacitor bank posses two part one is fixed part and another s variable part that is fixed capacitance and variable capacitance. The fixed part supply a fixed reactive power while variable part of the capacitor bank will supply changeable reactive power or virtual power to compensate the losses in power factor means reactive power which is needed to keep power factor at desired level.

Fixed part of the capacitor bank constitutes nearly 90% of the total capacitance and remaining 10% is adjusted with variable capacitor which is connected with switches and will be controlled by the application of fuzzy controller and comparator. The triggering signal will be initiated by the comparison of terminal voltage and the rated required voltage at the terminal end. The output terminal voltage is feedback to the comparator, which compares this with the reference value and fire signals to the relay for connecting or disconnecting variable capacitors.

The reactive power range is given by Eq. (8).

$$U^2\beta_c \leq Q_{svc} \leq U^2\beta_c + U^2\beta_{c1} \cdots\cdots\cdots 8$$

The reactive power injected can be given by following equation

$$Q_{svc} = U^2\beta_c + U^2\beta_{c1} * (0.05 * S_1 + 0.1 * S_2 + 0.15 * S_3 + 0.2 * S_4 + 0.25 * S_4) \cdots\cdots\cdots 9$$

Where the notation used is as elaborated in the text below:

U = Capacitor Bank Termicla Voltage
Q_{svc} = Magnitude of Reactive Power of Capacitor Bank which is required to be feed to Induction Generator
β_c = Susptancee of Capacitance
Si = Control Signals by Controller [13].

The response plot in the figure 8 presents voltage built process in the field winding of the self excited induction generator. The terminal voltage generated at the output port of the induction generator is due to interaction between residual magnetism in the core of the field winding of induction generator with that of the rotational motion of the rotor winding.

As there is residual magnetism is present in the close vicinity of core of the stator and when the rotate start to rotate in specific direction, due to interaction an induced emf is produced the winding of the rotor.

As the winding of the rotor is short-circuited an induced current will start to flow in the winding of the rotor. This flowing current in the winding of rotor will produces induced rotating field in the same direction as that of the core magnetizing force.

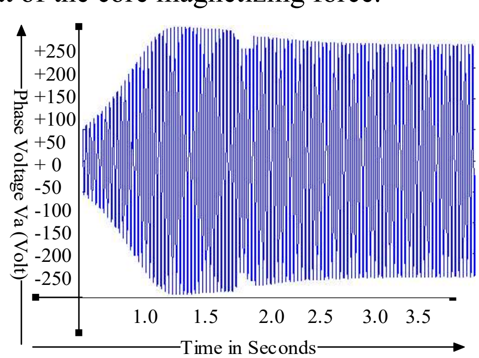

Figure-8.Terminal voltage of the SEIG from the initial condition to stable condition

This magnetizing force will be additive to the main filed winding and now a higher magnetic field will be created in the core of the stator. This again increases the induced voltage and current in the rotor winding of the rotor and so on. This is obvious that this process will came in to reality only when the rotational speed of the rotor of induction generator should be more that of the synchronous speed of the induction generator. If the rotational speed of the rotor of induction generator is less than the synchronous speed of generator than the voltage build and field produced will be in negative mode and will not add in constructive phase and instead of additive mode this will be in the negative mode will vanished the filed in the core of stator winding. This is the basic requirement of the successful operation of the induction generator. The same voltage building process is depicted in the response plote.

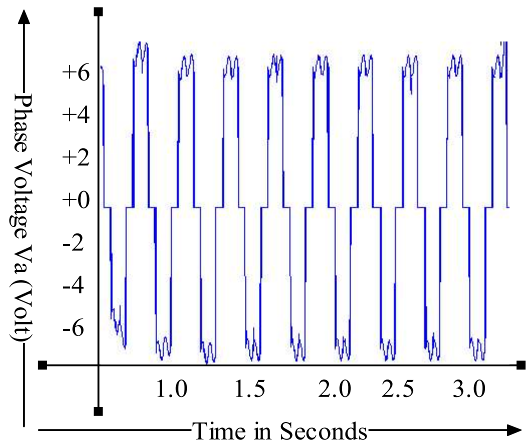

Figure-9. Load current due to application of rectifier load

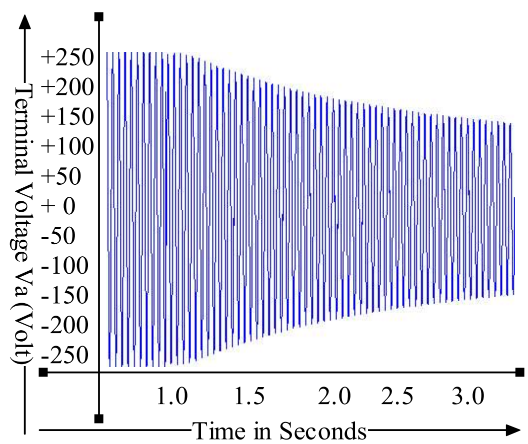

Figure-10. Change in terminal voltage due to change in excitation capacitance

From the above response plot, certain conclusion can be made which are defined in the next paragraph with relevant explanation. The Terminal Voltage of Induction generator will converges toward its target with specific delay time. The analysis results indicated that the suggested controller with the specific estimated genetic algorithm based fixed capacitor value will guarantees the solid stability under load change at terminal of Induction Generator.

This is also observed that in order to minimize the initial voltage built up time a larger value of fixed capacitance is needed at the starting up condition, which later is to be removed at running condition. The simulation response indicates that experimental voltage waveform of a stator phase during the voltage building up time will slowly- slowly increases with the optimal capacitance attached. The range of the capacitance must be within the limit otherwise the system will not get started or will be collapse as soon if this is loaded.

As soon the terminal of test system is start to supply a load, the Induction Generator will need more reactive power, and if the induction generator did not meet the required reactive power, than generator will extract this power from the grid and adversely affects the application.

Table-5. Value of Different Performance Parameter Using Different Capacitor Value

No	Quantity	Capacitance (Mathematical Calculation Base)	Capacitance (Fuzzy Logic Based)	Result with Optimal Capacitance	Percentage Improvement
01	Heat Dissipation	18%	13%	9%	23%
02	Uncertainty Response Time	0.9 Sec/operation	0.6%	0.4 Sec/operation	18%
03	Efficiency	82%	87%	91%	12%
06	Overall Performance	11%	12%	16%	13%
05	Voltage Regulation	12%	08%	05%	14%

6. CONCLUSION

The presented research article discusses the performance parameter of the Self Excited Induction generator. The overall performance an Self Excited Induction generator greatly depends upon the capacitor inserted in the stator winding of the Self Excited Induction generator. The value to be inserted capacitor is very critical for the performance of the Self Excited Induction generator. Three different techniques to calculate the value of capacitor had been presented. The article presented uses Genetic Algorithm to calculate the value of capacitor to be inserted. The simulation of the Self Excited Induction generator with the suggested value is done in the MATLAB virtual simulation environment. The simulation response shows that Heat Dissipation has been decreased up to 23% so the system efficiency and life time of assemble has been improved. Performance time has been improved by 12%, the system operation will be more stable. Efficiency has been improved by 12%. False triggering rate has been decreased by 6 %. Overall System performance has been enhanced by 13%.

7. FUTURE SCOPE

The induction generator is need of the time when the world facing energy crises across the countries in almost every nation of the globe. Induction generator is one of the most suitable candidates which can be proven to be most potential candidate for the alternative source of electric power generation. The work of the research can be extended in the field of variable loading condition such that SEIG feeding to unstable load in the stat alone application mode. The research can also be extended for the Self excited Induction Generator feeding to a power grid under variable turbine speed or in other word under changing power feed to power grid. Reactive power adjustment technique can alos be investigated for finer control and optimal response.

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