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Effect of Varying Wind Speed on the Performance of Three-Phase SEIG under Unbalanced Operations

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ABSTRACT: Self-excited induction generators are being extensively used for electricity generation through renewable sources like wind energy in windy areas. The operation of such generators in remote locations generally deals with unbalanced load at varying wind speeds. This puts a strong need for the analysis of such machines under unbalanced load at varying wind speeds. This paper presented a model which has been framed to analyze such machines with different wind speeds. A 15kw machine has been used for the analysis and the simulation results as obtained have been framed out the fruitful recommendations.

KEYWORDS: Self-excited induction generator (SEIG), wind energy, unbalanced operation, and renewable energy.

I. INTRODUCTION

Since past decades, the electricity has been the main concern for the development of a nation. The fast deterioration of fossil fuels and environmental safety are diverting the minds of scientist towards the non conventional energy recourses such as wind, solar, hydro, biomass, geothermal etc for the power generation. The induction generators are extensively used in remote and windy locations for the wind powered electricity generation due to its specialty to generate the power at varying wind speeds. Further these induction generators have the additional advantages such as low cost, reduced maintenance, rugged and simple construction, brushless rotor etc.

The performance analysis of three-phase self-excited induction generator under balanced operation is described using loop impedance and nodal admittance approach [1-2]. Malik et al [3] proposed the importance of capacitive requirement to operate the induction machine as self-excited induction generator. Sandhu et al [4] presented his new iterative model consisting a power source on rotor side. In addition to it, an methodology based on optimization technique was proposed in [5]. The operation of SEIG is controlled using genetic algorithm technique was presented in [6]. The work [1-6] is focused towards the operation of SEIG under balanced load as well as balanced excitation. However it has been found that the operation of SEIG is also contributed under unbalanced conditions also which might be due to single-phase load or three-phase unbalanced loading. Such operation of SEIG under unbalanced conditions may be due to aging effect or due to failure of some excitation capacitances. All such observation demands a detail analysis of SEIG under such unbalanced operations. Till now the related work contributes a less focus towards the operation of SEIG under unbalanced conditions. In the direction of the study of SEIG towards under unbalanced conditions, Bhattacharya et al [7] presented the importance of excitation balancing through symmetrical component approach. Murthy et al [8] carried the study of SEIG in this direction using symmetrical component theory while Wang et al [9] considered the same technique and proposed a two port network model. The losses in the core has been taken in to consideration [10] in which the magnetizing reactance for positive and negative sequence networks are taken to be same. The study in the direction of unbalanced operation of SEIG is forwarded by [11] which predict the effects of unbalancing due to change in load & excitation capacitance. Further

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chaturvedi et al [12] presented a new model for performance analysis of three phase self-excited induction generator under unbalanced operation. Further same model is adopted in [13] for unbalanced operation of SEIG under variation in load and excitation capacitance from open circuit to short circuiting of phases. A analysis for performance estimation of SEIG under different power factor loading is presented by [14].
In this paper, model as presented has been simulated in order to present the analysis of effect of varying wind speeds on the performance analysis of three-phase self-excited induction generator under unbalanced operations

II. MODELING

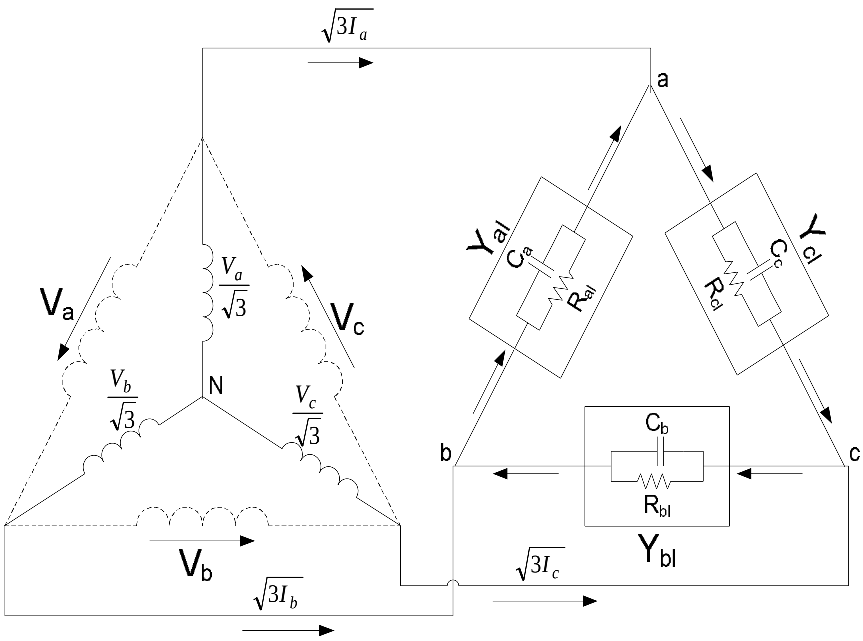

Figure1. Three-phase SEIG feeding three-phase load

Figure1 represents the three phase self-excited induction generator feeding a three phase load. Application of KCL at various nodes at load side and loop analysis of positive and negative sequence circuits [14] results in to a composite function as:-

$$\left[K^2(Y_\alpha K_z) - \{KY_d(1 - K_z) + Y_\beta\}\right] + \left[Z_{lp} + Z_1 + Z^I\right] + \left[Z_{ln} + Z_1 + Z^{II}\right] = 0 \qquad (1)$$

The composite function as in equation (1) consists of four unknown variables (F, K, X_{mp} , X_{mn}) which may be solved using genetic algorithm as an optimization tool in order to find out the appropriate solution of these variables for analysis of SEIG. After obtaining solution of composite function, performance of SEIG may be obtained from the performance equation as in [14].

III. RESULTS & DISCUSSION

Model of SEIG as proposed and explained in the previous section is adopted here to estimate the steady state performance of self-excited induction generator. Analysis has been carried out on a 4 pole, three-phase, 15 kw, 50hz, 415volts, 30A delta connected squirrel cage induction motor whose per phase parameters are R_1 = 0.029p.u, R_2 = 0.0309p.u,

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$X_1=X_2=0.1456$p.u. The saturation curve in per unit is $\frac{V_g}{F} = 0.49 + 0.813X_m - 0.302X_m^2$ while the unsaturated value of magnetizing reactance is 2.719p.u. The variation in load is achieved by variation in load resistance of phase-a only i.e R_{al} while load resistance of phase-b and phase-c are kept constant at 1.586p.u. The excitation capacitance of each phase is kept constant at 0.7753p.u throughout the operation.

Table:1 Variation in load resistance of phase-a at speed 1.028p.u

	Variation in R_{al}(p.u) at speed 1.028p.u				
	1.85	1.70	1.58	1.40	1.25
V_a(p.u)	1.014	1.008	1.002	0.99	0.978
V_b(p.u)	1.016	1.009	1.002	0.989	0.975
V_c(p.u)	0.999	1.001	1.002	1.004	1.005
I_a(p.u)	1.007	1.006	1.004	1.002	0.997
I_b(p.u)	0.956	0.982	1.004	1.047	1.09
I_c(p.u)	1.018	1.01	1.004	0.992	0.98
Pout	0.613	0.624	0.624	0.651	0.667
%n	68.82	68.76	68.7	68.6	68.53

Table 1 shows the Variation in load resistance of one phase (R_{al}) at a speed 1.028p.u. The variation in machine phase voltages and phase currents have been made by continuous variation in load resistance of phase- a while load resistance of phase-b and phase-c are kept constant at 1.586p.u

Table:2 Variation in load resistance of phase-a at speed 1.0 p.u

	Variation in R_{al}(p.u) at speed 1.0p.u				
	1.85	1.70	1.58	1.40	1.25
V_a(p.u)	1.036	1.029	1.023	1.009	0.995
V_b(p.u)	1.038	1.03	1.023	1.007	0.991
V_c(p.u)	1.02	1.022	1.023	1.023	1.02
I_a(p.u)	1.01	1.009	1.007	1.003	0.997
I_b(p.u)	0.96	0.985	1.007	1.05	1.08
I_c(p.u)	1.02	1.013	1.007	0.995	0.984
Pout	0.639	0.65	0.656	0.676	0.69
%n	69.5	69.44	69.4	69.3	69.24

The Variation in load resistance of one phase (R_{al}) at a speed 1.0p.u is shown in table-2. Machine phase voltages and phase currents have been examined by continuous variation in load resistance of phase- a while load resistance of phase-b and phase-c are kept constant at 1.586p.u

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Table:3 Variation in load resistance of phase-a at speed 0.98 p.u

	Variation in R_{al}(p.u) at speed 0.98p.u				
	1.85	1.70	1.58	1.40	1.25
V_a(p.u)	1.05	1.043	1.036	1.021	1.005
V_b(p.u)	1.053	1.044	1.036	1.02	1.001
V_c(p.u)	1.036	1.036	1.036	1.03	1.03
I_a(p.u)	1.013	1.01	1.008	1.002	0.995
I_b(p.u)	0.962	0.987	1.008	1.048	1.08
I_c(p.u)	1.021	1.014	1.008	0.996	0.984
Pout	0.658	0.668	0.677	0.692	0.704
%n	69.98	69.9	69.88	69.8	69.75

Table 3 shows the Variation in load resistance of one phase (R_{al}) at a speed 0.98p.u. Various phase voltages and phase currents of the machine have been obtained by continuous variation in load resistance of phase- a while load resistance of phase-b and phase-c are kept constant at 1.586p.u

Table:4 Variation in load resistance of phase-a at speed 0.96 p.u

	Variation in R_{al}(p.u) at speed 0.96p.u				
	1.85	1.70	1.58	1.40	1.25
V_a(p.u)	1.06	1.056	1.048	1.032	1.013
V_b(p.u)	1.067	1.057	1.048	1.03	1.01
V_c(p.u)	1.05	1.049	1.048	1.045	1.04
I_a(p.u)	1.014	1.011	1.007	1.009	0.992
I_b(p.u)	0.963	0.988	1.007	1.047	1.082
I_c(p.u)	1.021	1.014	1.007	0.995	0.983
Pout	0.675	0.685	0.693	0.706	0.715
%n	70.47	70.42	70.38	70.31	70.26

The Variation in load resistance of one phase (R_{al}) at a speed 0.96p.u is shown in table-4. The variation in machine phase voltages and phase currents have been made by continuous variation in load resistance of phase- a while load resistance of phase-b and phase-c are kept constant at 1.586p.u

Table-1 to table-4 shows the effect of variation in load resistance of phase-a under varying wind speed on phase voltage, phase currents, power output and efficiency of the machine. The observations made from variation in load resistance under varying wind speed are as follows:

1. Each table is corresponding to variation in load resistance at a particular speed. At any particular speed the voltage of phase-a and phase-b reduces by decreasing value of $R_{al.}$ However the change in voltage of phase-c is almost same. The same pattern is observed in the current of phase-a & phase-c while current in phase-b increases with decrease value of R_{al}. Power output increases as there is reduction in R_{al} where as there is slightly reduction in efficiency of the machine.
2. As per the analysis of table-1 to table-4, variation in speed at any particular load on the machine, we observed that reduction in speed results in to significant rise in phase voltages while there is almost negligible change in the

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values of phase currents of machine. However, decrement in speed results in to significant increase in power output and efficiency of the machine.

3. The machine should be operated slightly less speed to the base speed of the machine so as to obtain better performance of machine in terms of power output and efficiency.

IV. CONCLUSION

This paper presents the model which results in to a single composite objective function which has been analyzed using genetic algorithm for the analysis of self-excited induction generator. Further same model has been used to obtain the machine performance under varying wind speed. The simulated results as obtained using model under consideration are found to be useful to decide the suitable machine speed in order to obtained better performance in terms of power output and efficiency.

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