EXPERIENCE WITH SYNCHRONOUS GENERATOR MODEL USING PARTICLE SWARM OPTIMIZATION TECHNIQUE

N.RATHIKA[#1], Dr. A.SENTHIL KUMAR[*2], A.ANUSUYA [#3]

[1](Research Scholar, Anna University & Asst. Prof. EEE Dept. SKP Engineering College, Tamilnadu, India, rathika.nsd@gmail.com)

[2](Professor/EEE, Velammal Engineering College, Tamilnadu, India, vastham@gmail.com)

[3](PG Scholar, ME Power System Engineering, SKP Engineering College, Tamilnadu, India, a.anusuya18591@gmail.com)

Abstract:- This paper intends to the modeling of polyphase synchronous generator and minimization of power losses using Particle swarm optimization (PSO) technique with a constriction factor. Usage of Polyphase synchronous generator mainly leads to the total power circulation in the system which can be distributed in all phases. Another advantage of polyphase system is the fault at one winding does not lead to the system shutdown. The Process optimization is the chastisement of adjusting a process so as to optimize some stipulated set of parameters without violating some constraint. Accurate value can be extracted using PSO and it can be reformulated. Modeling and simulation of the machine is executed. MATLAB/Simulink has been cast-off to implement and validate the result.

Keywords: - Particle Swarm Optimization (PSO), Six phase synchronous generator (SPSG).

I. INTRODUCTION

Synchronous machines have been widely used in power systems mainly as generating unit they are not only the main generation units in large scale conventional power stations, but also in small and remote stand-alone systems. A multiphase system is a means of distributing alternating current electrical power. Multiphase systems have three or more energized electrical conductor carrying alternating currents with a definite time offset between the voltage waves in each conductor. In last two decades, investigation spread over the world indicate that technical and economic viability of using number of phases higher than three in multi-phase ac machines [1].The interest in multiphase machines lies mainly in the fact that with many phases the high currents concomitant with high power machines can be divided among more phases. Other advantages of six-phase machines compared to three-phase machine are low cost for finish equipment, lower noise than 3-phase system at the same power level, improved efficiency, reduced maintenance requirements, long life time, low harmonic distortion, low EMI, an increase in transmission ability, an advance of the voltage regulation so the reactive power control, an increase transmission performance due to them, it has more energy because they have lower losses, better stability than other systems. The experiments were carried out on six-phase synchronous generator for (i) constant voltage operation (ii) constant frequency/speed operation for better voltage regulation [2].In Steady State Analysis of Self-excited Six-phase Induction Generator Fmincon is implemented to solve the resultant matrix where equations are developed by nodal admittance are solved by Fmincon. This method has the advantage that there is no need to manually derive the complex coefficient of the polynomial equations [3]. Comparisons between the six- phase and conventional three-phase generator performance gives, electrical quantities wave form, improvement of the harmonic distortion, performance of damper windings is better than among others [4].Modeling is an activity the aim to which is to make a particular part or feature of the world easier to understand, define, quantify, visualize or simulate.

The aim is to meet both the customer who is purchasing the generator with increased efficiency with a minimum change in price, and the provider, aiming to lessen the impact on the existing manufacturing process by use of some approaches and optimization tools [5].Particle swarm optimization (PSO) is an artificial intelligence (AI) technique that can be used to find approximate solutions to tremendously difficult or impossible numeric maximization and minimization problems. PSO is loosely modeled on group behavior, such as bird flocking and fish schooling. In general, PSO is well suited to numeric problems with dimensions of 2 or larger. In most situations, PSO must have some constraints on the range of possible x values. When using PSO, a possible solution to the numeric optimization problem under investigation is represented by the position of a particle. Additionally, each particle has a current velocity, which represents a magnitude and direction toward a new, presumably better, solution/position. A particle also has a measure of the quality of its current position, the particle's best-known position (that is, a previous position with the best known quality), and the quality of the best-known position. The Particle class has five public data members: position, fitness, velocity, best Position and best Fitness. When using PSO, for simplicity I prefer using public scope fields, but you may want to use private fields along with get and set properties instead. The field named position is an array of type double and represents a possible solution to the optimization problem under investigation. Although PSO can be used to solve non-numeric problems, it's generally best suited for solving numeric problems. Field fitness is a measure of how good the solution represented by position is. For minimization problems, which are the most common types of problems solved by PSO, smaller values of the fitness field are better than larger values; for maximization problems, larger values of fitness are better.

II. MODELING OF SIX PHASE SYNCHRONOUS GENERATOR

Modeling of six-phase synchronous machine can be achieved in several ways. One way is to use two doubly star machines with a 30 electric degrees phase-shift between the two stars. Another way is to use a split phase machine, which can be built by equally dividing the phase belt of a conventional three-phase machine into two parts with spatial phase separation of 30 electrical degrees. Finally the third way uses the doubly star machines with a star-triangle transformer at the output of one machine to get a 30° electrical degrees phase-shift between the two machines.In double star synchronous machine (DSSM) is built with two symmetrical 3-phase armature-winding systems, electrically shifted by 30 degrees. In order to obtain a model of double star synchronous machine, the MMF in air-gap have a sinusoidal repartition and the saturation of the iron in machine is neglected. The stator voltage equation for six-phase can be written as a set of voltage vectors corresponding to the switching mode is chosen to offer a maximum voltage and keep the harmonics at a minimum [6].In case of double star synchronous machines establish an advantageous choice compared to classical synchronous machines, such as relatively low torque ripple produced [7]. The dynamic average-value model of the rectifier circuit relies upon establishing a relationship between the dc-link variables on the one side and the ac variables transferred to a suitable reference frame on the other side [8].

To be able to get a time independent equation system, the stator quantities (voltages, currents and flux linkages) are transformed using the dq_0transformation. This transformation, sometimes called the Park- or the Blondel transformation, is a transformation to rotor coordinates. Using these techniques, it is possible to transform the phase variable machine description to another reference frame. By judicious choice of the reference frame, it proves possible to simplify considerably the complexity of the mathematical machine model. While these techniques were initially developed for the analysis and simulation of ac machines, they are now invaluable tools in the digital control of such machines.

The behavior of the self-inductance of a single phase of the stator

$$L_{ii} = (L_{s1}+L_{s2})+L_m \cos 2(\theta+\alpha_i) \quad (1)$$

The mutual inductance between two phases of the stator can be represented by

$$L_{ik} = -M_s - L_m . \cos|2\ (\theta+\alpha_{ik})| \quad (2)$$

The operation of the machine, it becomes feasible to obtain expressions to correlate the magnetic flux and their respective currents that are present in windings of the generator. These equations are given by

$$[\lambda]=[L]\ [i] \quad (3)$$

The electromagnetic torque can be obtained from the principle of energy conservation

$$T_e = \frac{P}{2} \sum_i \sum_k i_i i_k \frac{dL_{ik}}{d\theta} \quad (4)$$

The dynamics of the movement of the synchronous machine can be given by

$$J\frac{d^2\theta}{d^2\, t} = T_T - T_e \quad (5)$$

The stator voltage equation for six-phase can be written as:

$$[V_s] = [Rs][i_s] + d/\, dt([L_{ss}][i_s] + [M_{sr}]i_f) \quad (6)$$

with

$$[v_s] = [va1\ va2\ vb1\ vb2\ vc1\ vc2]^T \quad (7)$$

$$[i_s] = [ia1\ ia2\ ib1\ ib2\ ic1\ ic2]^T \quad (8)$$

The original six dimensional system of the machine can be decomposed into three orthogonal subspaces

(α,β), (Z1,Z2) and (Z3,Z4)

$$[F_\alpha\ F_\beta\ F_{Z1}\ F_{Z2}\ F_{Z3} F_{Z4}]^T = [T_s][F_s] \quad (9)$$

III PARTICLE SWAM OPTIMIZATION

Optimization determines the best-suited solution to problem under given circumstances. It refers to both minimization and maximization tasks. Since the maximization of any function is mathematically equivalent to the minimization of its additive inverse, the term minimization and optimization are used interchangeably [7]. For this reason, now-a-days, it is very important in many professions. Optimization problems may be linear (called *linear optimization* problems) or non-linear (called *non-linear optimization* problems).*Non-linear optimization* problems are generally very difficult to solve. Optimization is a mathematical technique that concerns the finding of maxima or minima of functions in some feasible region. There is no business or industry which is not involved in solving optimization problems. A variety of optimization techniques compete for the best solution. Particle Swarm Optimization (PSO) is a relatively new, modern, and powerful method of optimization that has been empirically shown to perform well on many of these optimization problems. It is widely used to find the global optimum solution in a complex search space. Particle swarm optimization (PSO) with a constriction factor is used for Synchronous machine parameter identification method that allows for a more well-organized convergence in the optimization and parameter identification strategy to identify the characteristics of a large synchronous generator [9]. PSO based identification for non-linear system is a better applicant both in terms of convergence speed as well as number of input samples used even under noisy condition [10].

PSO is a robust stochastic optimization technique based on the movement and intelligence of swarms. PSO applies the concept of social interaction to problem solving. It uses a number of agents (particles) that constitute a swarm moving around in the search space looking for the best solution. In case of birds each particle is treated as a point in a N-dimensional space, which adjusts it's "flying" according to its own flying experience as well as the flying experience of other particles. A number of basic variations have been developed due to improve speed of convergence and quality of solution found by the PSO.PSO is different from other technique and this technique is faster than real time simulation, it can also be extended to other online identification and optimization problem [11]. On the other hand, basic PSO is more appropriate to process static, simple optimization problem. PSO has been used by many applications of several problems. The algorithm of PSO emulates from behavior of animals societies that don't have any leader in their group or swarm, such as bird flocking and fish schooling. Typically, a flock of animals that have no leaders will find food by random; follow one of the members of the group that has the closest position with a food source (potential solution). The flocks achieve their best condition simultaneously through communication among members who already have a better situation. Animal, which has a better condition, will inform it to its flocks and the others will move simultaneously to that place. This would happen repeatedly until the best conditions or a food source discovered. The PSO method is one of the methods under the wide category of Swarm Intelligence methods for solving optimization problems. PSO do not require any mathematical decorum of the hybrid system except of an error-prediction function evaluable [12]. PSO technique used for Parameter Identification of Excitation System yields the advantages of few input data required and little model-specified, flexibility, and the simplicity of its mechanism [13].Particle Swarm Optimization technique has been successfully applied for identifying the Torus generator equivalent circuit parameters. The constraint of this method is that the accuracy depends on the search range [14].PSO technique is best and well suited for parameter optimization and it can extract accurate value [15].

It is a population-based search algorithm where each individual is referred to as a particle and represents a candidate solution. Each particle in the PSO flies through the search space with an adaptable velocity that is dynamically modified according to its own flying experience and that of the other particles. In PSO, each particle strives to improve itself by imitating the traits of its successful peers. Further, each particle has a memory and hence is capable of remembering the best position in the search space it visited. The position corresponding to the best fitness is known as P_{best}, and the best one among all particles in the population is called g_{best} [g_{best}]. The features of the searching procedure can be summarized as follows:

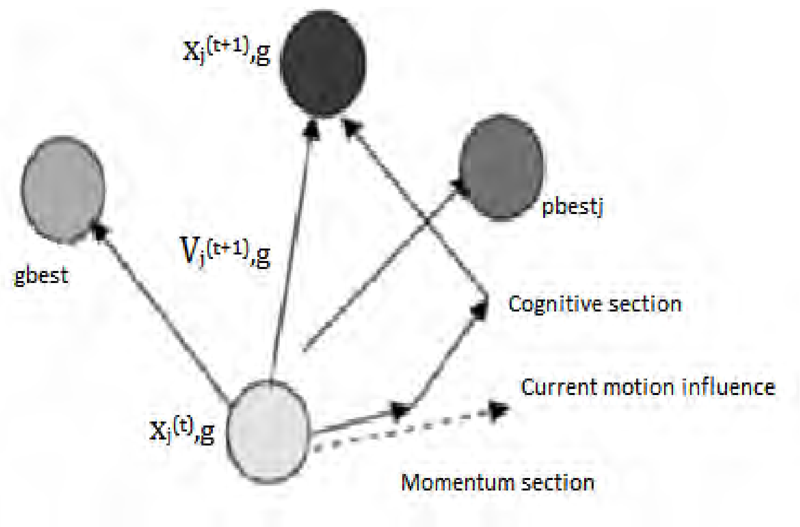

Fig 1 Deception of velocity and position updates in the particle swarm optimization technique

• The initial positions of p_{best} and g_{best} are different. However, using the different direction of p_{best} and g_{best}, all agents gradually draw close to the global optimum.

• The modified value of the agent position is continuous, and the method can be applied to the continuous problem. However, the method can also be applied to the discrete problem using grids for the XY position and its velocity.

• There are no inconsistencies in searching procedures even if continuous and discrete state variables are utilized with continuous axes and grids for the XY positions and velocities. That is, the method can be applied to mixed-integer nonlinear optimization problems with continuous and discrete state variables naturally and easily.

• The above concept is explained using only the XY axis (two-dimensional space). However, the method can easily be applied to the n dimensional problem. The modified velocity and position of each particle can be calculated using the current velocity and the distance from p_{best} to g_{best}.

Fig. 1 shows the velocity and position updates of a particle for a two-dimensional parameter space. The computational flow chart of the PSO algorithm is shown in Fig. 2.

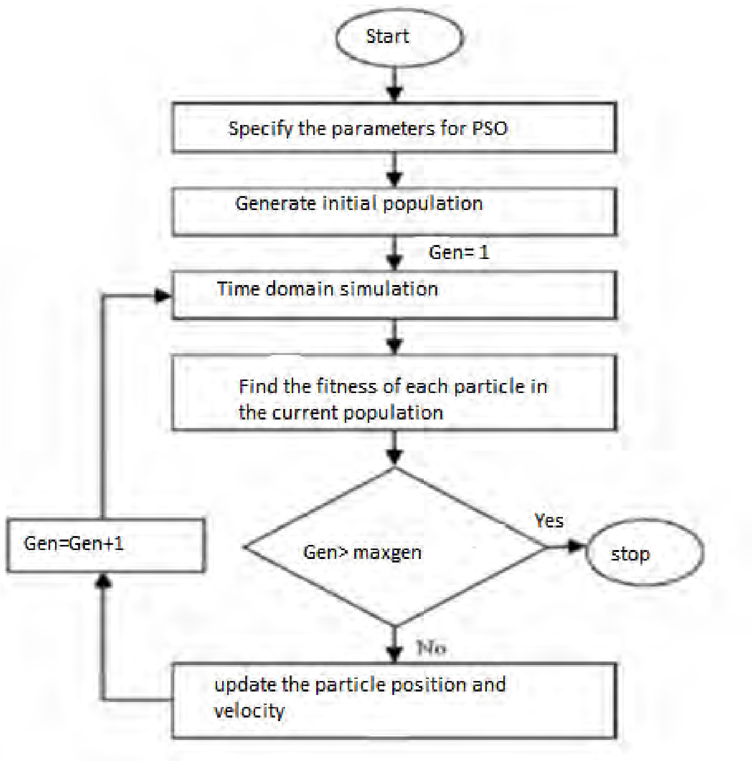

Fig 2 Flowchart of the particle swarm optimization algorithm

IV RESULTS AND DISCUSSION

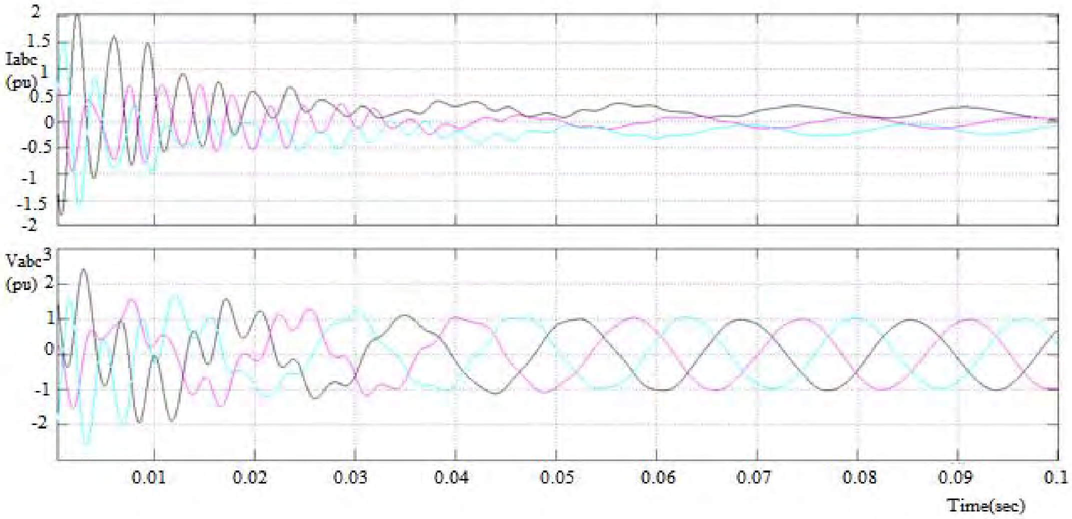

Fig 3 Stator voltage and current (abc)

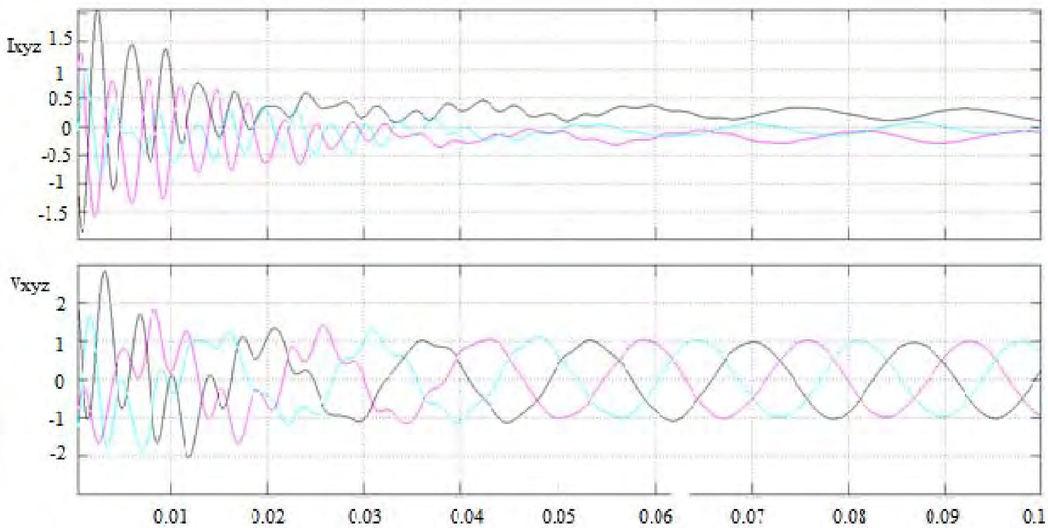

Fig 4 Stator voltage and current (xyz)

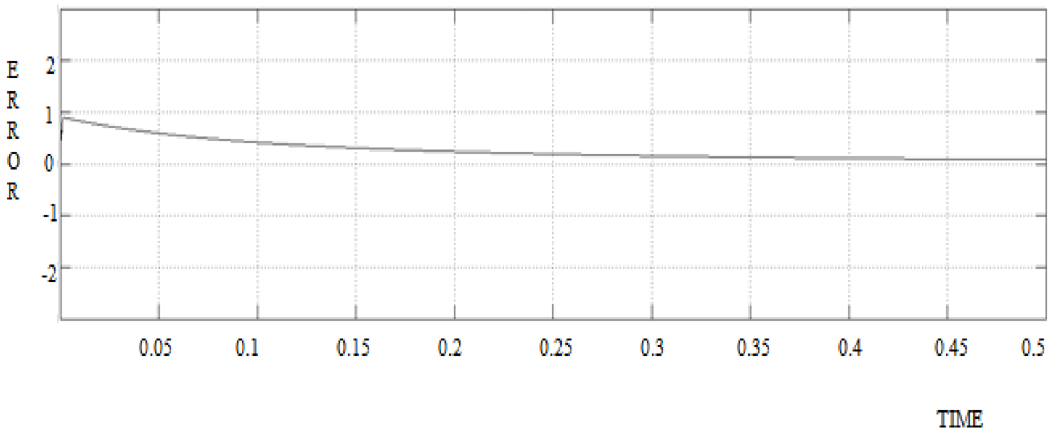

Fig 5 Error in power

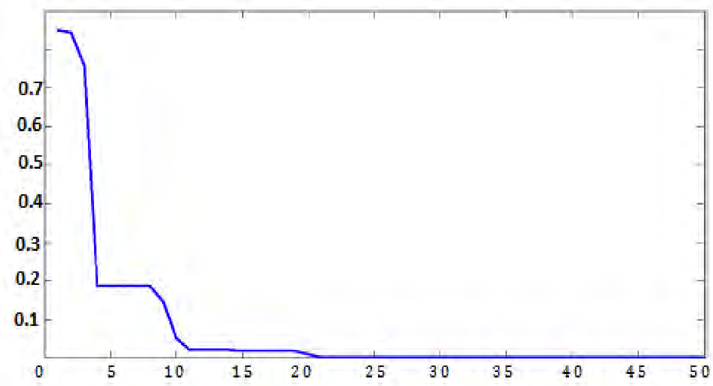

Fig 6 Plot of losses vs Iterations

Variables	0.21 - 0.4	0.01 - 0.2	0.0001 – 0.01
Optimal solution	0.21 - 0.021	0.12308 0.09752	0.00164 0.00140
Elapsed time	2246.2159	2170.6736	2228.0324
Losses	0.918332	0.000021	NAN

TABLE 1
Performance data with PSO approach

The above comparison table shows that power losses are minimized with the elapsed time of 2170.6736. The optimal solution is obtained with the limits of 0.12308 0.09752.As the variable goes less than 0.01 the losses are fully minimized.

V CONCLUSION

PSO is an intelligent computational method based on a stochastic search that has been shown to be a versatile and efficient tool for complicated engineering problems. The PSO technique guides to narrow convergence solution of non linearity in this model and for loss minimization. The need of optimization is essential in synchronous generator for accurate modeling and parameter estimation is done effectively. In power system operation optimization is used for solving the problem of uncertainty analysis in power system, optimal reconfiguration of electrical distribution network, optimal load scheduling, reactive power optimization, steady state security regions, optimal power flow, unit commitment, multi area system economic dispatch, security constrained economic dispatch, classic economic dispatch, sensitivity calculation, power flow analysis. To show the validity of the mathematical analysis and, hence, to reduce the power losses, simulations works are carried out for the system using MATLAB SIMULINK.

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Dr. A.Senthil Kumar, obtained is Bachelor's Degree (1996) in Electrical and Electronics Engineering in first class from University of Madras, Chennai, Tamil Nadu. He obtained his Master's degree (2000) in Power Electronics and Drives in first class from Bharathidasan University, Trichy, Tamilnadu and also he obtained his Master's degree (2006) in Human Resource Management in first class from TNOU, Chennai. He completed his Doctoral degree (2010) in the area of Electrical Engineering from Indian Institute of Technology Roorkee, Uttarakhad, India. He also completed his Post Doctoral research fellow in Centre for Energy and Electrical Power, Electrical Engineering Department, Faculty of Engineering and built environment, Tshwane University of Technology, Pretoria, South Africa for a period of one year from 2012-2013. He obtained many awards and certificates during M.E and Ph.D studies. He has 17 years of teaching and research experience. He has published 15 papers in international journals and presented 30 papers in international and national conferences. He has attended many international seminars and workshops. He is a life member of many professional body memberships like ISTE, IEI, CSI, IAENG, IACSIT etc., He visited foreign country such as Hong Kong, Chengudu & Mauritius. Financially supported by DST, CSIR and NRF. He has delivered state of the art lectures in many educational institutions and professional societies. He is currently doing ongoing project funded by AICTE worth of 33 lakhs. His research interests include Multiphase Machines, Power Electronics, and Renewable Energy Generation Source, Microcontroller & VLSI application in Power Electronics & Electric Drives, Active Filters Stability and System Analysis. Currently he is working as Professor/EEE at Velammal Engineering College, Chennai, Tamilnadu.

N.Rathika obtained her BE (2000) Electrical and Electronics Engineering degree with first class from University of Madras and completed her M.E (2006) in Power Electronics and Industrial Drives in first class with distinction from Sathyabama University. She has 12 years of teaching experience. She is a PhD research scholar of Anna University, Chennai. She has attended many Faculty Development Programmes and Workshops. She presented 6 papers in International & national Conferences. She has published 2 international journals. At present she is working as a Assistant Professor in EEE department of SKP Engineering College, Tiruvannamalai, Tamilnadu, India. She is a member of IEEE, ISTE. Her areas of interest are Electrical Machines, Power Electronics, Electrical Drives and Soft computing techniques.