Lecture Notes in Networks and Systems 41

Utpal Biswas
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Preface

A revolutionary change has been observed in the field of computer, communications, control and systems during the last two decades. Keeping this in mind, Asansol Engineering College, Asansol, West Bengal (WB), India, organised the first international conference on Emerging Trends in Engineering and Science (ETES 2018) held on 23 and 24 March 2018. ETES 2018 focuses on the integration of intelligent communication systems, control systems and devices related to all aspects of engineering and sciences. ETES 2018 aims to provide a forum and vibrant platform for researchers, academicians, scientists and industrial practitioner to share their original research work, findings and practical development experiences. The proceedings will be published in the Lecture Notes in Networks and Systems book series of Springer. This book contains high-quality research papers divided into 56 chapters which are completely relevant to this lecture note series.

The general aim of the conference is to promote international collaboration in education and research in all fields and disciplines of engineering. More than 225 researchers and delegates attended the conference. ETES 2018 is an international forum for those who presented their research findings. It also provides the opportunity to presenters to discuss the main aspects and the latest results in the field of education and research.

The organising committee is extremely grateful to the authors who had shown a tremendous response to the call for papers. Over 135 papers were submitted from the researchers, academicians and students on a wide area of three parallel tracks in intelligent communication systems, control systems and devices, along with a poster presentation session. A total of 56 papers are accepted for publication with Springer.

We are obliged to Prof. S. K. Dey, honourable Pro-Vice Chancellor, Maulana Abul Kalam Azad University of Technology, West Bengal (MAKAUT, WB), India; Prof. S. P. Mukherjee, Centenary Professor, Calcutta University, Kolkata, WB, India; Prof. N. R. Das, Calcutta University, Kolkata, WB, India; Prof. N. Ganguly, IIT Kharagpur, WB, India, for their confidence they have invested on us for organizing this international conference.

Asansol, India Sandip Haldar

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Transient Voltage Analysis of a Hybrid Power System Model by Using Novel Symbiosis Organism Search Algorithm

Abhik Banerjee, Pabitra Kumar Guchhait, Apurba Chatterjee and V. Mukherjee

Abstract Symbiosis organism search (SOS) algorithm is a novel meta-heuristic search algorithm based on the interactions of organisms in the environment. In SOS, the behaviour of the organisms in the nature is taken into consideration for the purpose of optimization. In this paper, the effectiveness of this SOS algorithm is being tested for the compensation of reactive power of the isolated hybrid power system. In the tested isolated power system, this paper has been considered as a wind engine based induction generator and a diesel engine based synchronous generator. Under the running condition, minimizing the gap between the demand and supply of reactive power has been provided by a static synchronous compensator (STATCOM). In the studied model, a PID controller is also carried out to track the degree of reactive power compensation under small input perturbation.

1 Introduction

Now, the renewable energy sources are more important than the conventional energy sources due to its various advantages. But renewable energy sources have the major disadvantage is that it is intermittent in nature. So now, the hybrid energy system is often much acceptable than any other energy system. Usually, the hybrid energy sys-

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tem consists of synchronous generator (SG) and induction generator (IG). The hybrid energy system may consist a diesel engine based synchronous generator (SG) and a wind engine based induction generator (IG). For running the hybrid energy system, the synchronous generator provides active as well as reactive power to the system but the induction generator only provides active power to the system. Induction generator required reactive power for its operation under the running of a constant slip (s). Most of the loads are reactive in nature so to drive a specified load their always required active as well reactive power. So, in the hybrid system, there is a mismatch in reactive power occurred. The deficit or excess in reactive power of a hybrid power system may cause various problems like abruptly voltage fluctuations, steady state as well as transient stability. So, reactive power compensation is required for the healthy operation of the system. The requirement of desirable reactive power may provide by the various flexible ac transmission systems (FACTs) devices [1]. A shunt or series reactor may provide adequate amount of reactive power [2]. In the paper [3], condenser provides the deficit of reactive power but it may not be suitable for the hybrid system because it has no capability to maintain the stability when abruptly voltage fluctuations have occurred in the system. So, for healthy operation of the isolated hybrid power system, the FACTs devices like SVC, STATCOM, TCSC, etc., are used. There are various papers [4–9] where SVC-, TCSC- and STATCOM-based FACTs controller is used to maintain the reactive power of the system. Static synchronous compensator (STATCOM) has various advantages than the SVC controller [10]. STATCOM has the tremendous capability to perform the system as a stable one when the system senses large disturbances [11]. In the research paper [11], STATCOM-based PI controller is described to maintain the reactive power of the isolated diesel-wind hybrid power system. The STATCOM-PI controller parameters are optimized using algorithms GA, ANN and ANFIS.

Symbiosis organism search (SOS) algorithm is a new meta-heuristic search algorithm developed by Cheng and Prayogo [12] in 2014 inspired from the behaviours of various living organisms in nature. SOS algorithm has been developed with the three simple basic steps that include: (a) mutualism phase where the two organisms in nature interact with each other and both of them are benefitted (e.g. Oxpecker and Zebra). (b) commensalism phase where the two organisms interact with each other and in this case, one is benefitted but another may or may not be benefitted (e.g. Tree and Spider). (c) Parasitism phase where the one becomes beneficial from the interaction and it is the fittest in the system and fully destroyed the other (e.g. Plasmodium parasite and human body). The SOS algorithm is better than the other algorithms because of its no specific parameters that should be optimized and it has the quick convergent rates than the others.

In the present work, the objectives are (a) to develop a isolated hybrid wind-diesel power system model (b) use STATCOM-PID controller to tune of the parameters and to maintain the system stability under small voltage fluctuations and (c) a novel heuristic algorithm SOS is used to optimize the parameters of the isolated hybrid system and compare the results with ALO-based algorithm results for its efficacy.

2 Mathematical Modelling of Isolated Hybrid Power System

The single line diagram of the depicted hybrid power system model and the Simulink model of this design model are given in Figs. 1 and 2.

From Fig. 1, it has been shown that the under normal operating condition, the real and reactive power balance equations are written as

$$\Delta P_{SG} + \Delta P_{IG} - P_{load} = 0 \tag{1}$$

$$\Delta Q_{SG} + \Delta Q_{STATCOM} - \Delta Q_{IG} - Q_{load} = 0 \tag{2}$$

When any sort of disturbances occurs in the system, the reactive power demanded by the load as well as IG is increased therefore a reactive power mismatch happens in the system. But the grid has a permissible limit to control the certain tolerance. Therefore the surplus of reactive power may cause effect the voltage profile. So, reactive power control is more necessary to maintain the terminal voltage profile (Table 1).

The Simulink model of the isolated hybrid wind-diesel model in s-domain has been focused in Fig. 2. The principal transfer function of the studied hybrid model is given in s-domain as

$$\Delta V(s) = \frac{K_V}{(1 + sT_V)}[\Delta Q_{SG} + \Delta Q_{STATCOM} - \Delta Q_{IG} - Q_{load}] \tag{3}$$

For any sort of disturbances, the incremental change of reactive power in SG, IG and STATCOM is written as

$$\Delta Q_{SG} = K_1 \Delta E_q(s) + K_2 \Delta V(s) \tag{4}$$

$$\Delta Q_{IG}(s) = K_5 \Delta V(s) \tag{5}$$

$$\Delta Q_{STATCOM}(s) = K_j \Delta\alpha(s) + K_k \Delta V(s) \tag{6}$$

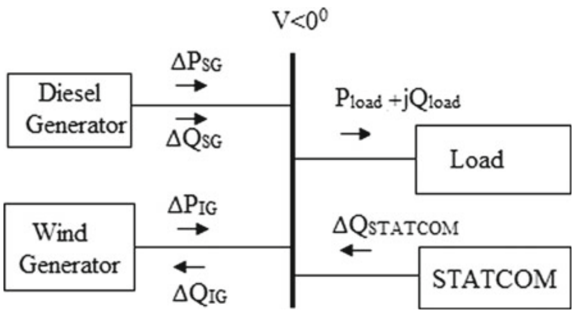

Fig. 1 Single line block diagram of the studied model

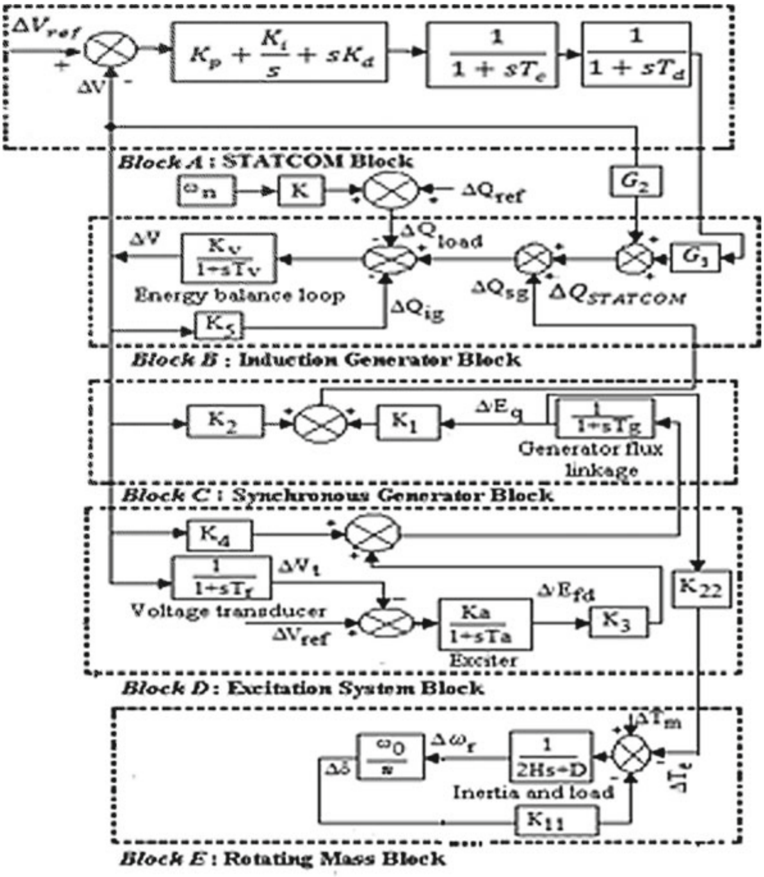

Fig. 2 Transfer function model of the studied hybrid system with STATCOM

The various parameter values of the studied model are given in appendix Tables 2 and 3.

3 Objective Function Formulation of the Present Problem

The objectives of the present work may be worked out by doing the mathematical analyses of the system eigenvalues. Eigenvalue analysis approach is done to tune the parameters of the isolated hybrid power system model and to achieve some degree of relative stability as well as the damping of the electrical modes of oscillations [1, 13]. An objective function based on eigenvalue analysis is structured as [13]

Table 1 Optimal parameters values and the best fitness value for different algorithms under different input conditions

Model + STAT-COM	V and Xeq in p.u.	Optimal parameters value	Best fitness value	Elapsed time
SOS	1.03; 1.0	−31.8058, 6.0802, 0.0010, 0.7466, 0.0010	23.8103	4.331280
ALO		1.0004, 10.0000, 31.2518, 0.5655, 0.2613	26.4590	8.404380
SOS	1.01; 1.0	−19.8890, 8.3208, 2.0852, 0.7410, 0.1268	23.8103	4.445983
ALO		1.0001, 10.0000, 30.2851, 0.5916, 0.2245	26.2601	8.154146
SOS	1.0; 1.08	−25.8571, 10.0000, 0.0010, 0.7708, 0.0807	23.8103	4.149989
ALO		1.0037, 10.0000, 25.8699, 0.4227, 0.5074	26.1604	8.156278
SOS	1.0; 0.93	−21.8773, 6.0716, 0.0010, 0.7422, 0.1749	23.8103	4.387885
ALO		1.0044, 10.0000, 26.2550, 0.3906, 0.5284	26.1619	8.108451
SOS	1.0; 0.4752	−23.0773, 7.8866, 0.0010, 0.7672, 0.0398	23.8103	3.975375
ALO		1.0000, 10.0000, 29.8870, 0.6032, 0.2054	26.1650	7.963798
SOS	0.99; 1.08	−21.6163, 9.8857, 0.0010, 0.1492, 0.7547	23.8103	4.162304
ALO		1.0000, 10.0000, 34.2157, 0.0100, 0.6459	26.0735	8.059489
SOS	0.97; 1.08	−23.1996, 8.0000, 0.0010, 0.7485, 0.0513	23.8103	4.473538
ALO		1.0002, 10.0000, 22.7910, 0.5080, 0.4621	25.8705	8.127750
SOS	0.97; 0.93	−32.5864, 10.0000, 0.0010, 0.0010, 0.8577	23.8103	4.015157
ALO		1.0000, 10.0000, 23.3619, 0.5489, 0.4034	25.8703	8.178638
SOS	0.97; 0.4752	−15.7685, 9.2936, 0.0010, 0.7458, 0.2418	23.8103	4.552873
ALO		1.0000, 10.0000, 22.7246, 0.4939, 0.4783	25.8693	8.157957
SOS	1.01; 1.08	−26.3569, 9.5277, 0.0010, 0.0010, 0.7772	23.8103	4.011459
ALO		1.0000, 10.0000, 26.6509, 0.4561, 0.4688	26.2596	8.066174
SOS	1.01; 0.93	−28.5989, 9.6884, 0.0010, 0.0010, 0.8176	23.8103	4.132353
ALO		1.0004, 10.0000, 27.1707, 0.5234, 0.3856	26.2592	8.242917
SOS	1.01; 0.4752	−19.0985, 8.5236, 3.4818, 0.1115, 0.7412	23.8103	4.166023
SOS		1.0002, 10.0000, 26.6894, 0.4514, 0.4725	26.2567	8.066964

$$J = 10 \times J_1 + 10 \times J_2 + 0.01 J_3 + J_4 \tag{7}$$

During the optimization process, the various weighting factors of the given equation J_1, J_2, J_3 and J_4 are chosen properly and make them mutually competitive. The objective function J is made to be minimum as much as possible in the optimizing process such that the closed-loop poles of the system consistently pushed further left of the *jw-axis* that is why the relative stability of the system enhanced and the damping ratio ε_0 be increased. As much as, the minimization of objective function J then the relative stability of the system can be enhanced in greater extension.

Table 2 Data used for the proposed hybrid model

Synchronous generator	Induction generator	Load	STATCOM
$P_{SG} = 0.4$ p. u. kW	$P_{IG} = 0.6$ p. u. kW	$P_{load} = 1.0$ p. u. kW	$Q = 0.841$ p.u. kVAR
$Q_{SG} = 0.2$ p. u. kVAR	$Q_{IG} = 0.291$ p. u. kVAR	$Q_{load} = 0.75$ p. u. kVAR	$\alpha = 138.8°$
$E_q = 1.12418$ p. u.	$P_{in} = 0.667$ p. u. kW	Power factor = 0.8	
$\delta = 17.2483^0$	$\eta = 90\%$		
$E_q^{'} = 0.9804$ p. u.	Power factor = 0.9		
$U = 1.0$ p. u.	$r_1 = r_2^{'} = 0.19$ p. u.		
$X_d = 1.0$ p. u.	$x_1 = x_2^{'} = 0.56$ p. u.		
$X_d^{'} = 0.15$ p. u.	$S = -3.5\%$		
$T_{do}^{'} = 5.0$ s	–		

Table 3 Consists of the various parameters of STATCOM with their range of values

Name of the controller	Controller parameters	Minimum value	Maximum value
STATCOM	T_c	0.001	1.67
	T_d	0.001	1.67

4 Brief Discussion on the Proposed Algorithm

4.1 Symbiosis Organism Search Algorithm

SOS [12] algorithm is much better than any other algorithm due to its less complexity and no permanent optimization parameters. SOS algorithm developed in three basic steps.

4.1.1 Mutualism Phase

In mutualism phase, consider two organisms randomly from the ecosystem X_i and X_j where $(X_i \neq X_j)$ are mutually interact with each other and in this interactions both the organism are benefitted and update their fitness to the better one. The new organisms are updated as

$$X_{inew} = X_i + rand(0, 1) * (X_{best} - Mutual\_vector * BF_1)$$

$$X_{jnew} = X_j + rand(0, 1) * (X_{best} - Mutual\_vector * BF_2)$$

$$Mutual\_vector = \frac{X_i + X_j}{2}$$

where $rand(0, 1)$ is the random variable range from 0 to 1 and BF_1 and BF_2 are the benefitted factor usually chosen either 1 or 2. $Mutual\_vector$ represents the relationship between the organisms X_i and X_j and the benefitted factors represent the level of benefit which they got benefit from the mutual interactions, i.e. either it will be fully or partially benefitted. The equations represent the increase of degree of adaptation in the ecosystem where X_{best} is the highest degree of adaptation to the ecosystem. The new solution accepted when the fitness function is better than the previous one.

4.1.2 Commensalism Phase

In commensalism phase of SOS algorithm, consider the ith and jth organisms X_i and X_j where $(X_i \neq X_j)$ from the ecosystem randomly thereafter they are allowed to interact with each other and in this phase X_i tries to get benefitted without hampering X_j. Therefore, the new solution of X_i will be as $X_{inew} = X_i + rand(-1, 1) * (X_{best} - X_j)$ Where the benefit result for adaptation of X_i is provided by X_j from $(X_{best} - X_j)$.

4.1.3 Parasitism Phase

In this phase, an organism X_i is selected from the ecosystem which is like Anopheles mosquitoes. First, anopheles mosquitoes create artificial parasite name as Parasite_vector and this Parasite_vector is produced similar X_i randomly with all its possible dimensions and thereafter choose an organism from the ecosystem X_j that is host (human body). If the fitness value of X_j is better than Parasite_vector, then host builds immunity in the ecosystem and parasites no longer exist and vice versa effect also happened and then parasites kill the organism X_j. The flowchart of SOS algorithm is presented in Fig. 3.

5 Simulation Result Analysis

The simulations of the present work are carried out on the isolated hybrid power system model using STATCOM-PID controller and the observations are presented below.

The various state differential components of the given model are depicted below: