Lecture Notes in Electrical Engineering 626

H. S. Saini
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D. M. Vinod Kumar
K. S. Chandragupta Mauryan *Editors*

Innovations in Electrical and Electronics Engineering

Proceedings of the 4th ICIEEE 2019

Springer

Lecture Notes in Electrical Engineering

Volume 626

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ISSN 1876-1100 ISSN 1876-1119 (electronic)
Lecture Notes in Electrical Engineering
ISBN 978-981-15-2255-0 ISBN 978-981-15-2256-7 (eBook)
https://doi.org/10.1007/978-981-15-2256-7

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Preface

The Fourth International Conference on Innovation in Electrical and Electronics Engineering (ICIEEE 2019) was organized on July 26 and 27, 2019, by the Department of Electrical and Electronics Engineering at Guru Nanak Institutions Technical Campus, Hyderabad. This conference has provided an interactive platform for researchers, scientists, technocrats, and academicians to exchange their innovative ideas and research findings in the field of electrical and electronics engineering. Our earlier conferences got a huge success and acknowledged by national and international eminent scholars with their active participation and contribution. The distinguished speakers from India and abroad have shared their innovative ideas and technologies on this topic.

Over 256 papers were received in which 79 high-quality papers have been selected for Springer Conference Proceedings publication. The authors of these particular papers presented them remarkably. Parallel sessions were also conducted to accommodate all the authors, and ample time was allotted to discuss their ideas. We, the Department of Electrical and Electronics Engineering, made all arrangements for smooth conduct of this conference and received positive feedback that gives good encouragement for us to conduct such conferences in the future.

We would like to thank all the keynote speakers, participants, speakers of the pre-conference tutorial sessions, session chairs, committee members, reviewers, international and national board members, Guru Nanak Institutions' management and all the people who have directly or indirectly contributed to the success of ICIEEE 2019. The institutions' editorial board members expressed their sincere thanks to Springer Editorial Team for their kind support in publishing the papers as a part of the "Lecture Notes in Electrical Engineering" Series.

Hyderabad, India — Dr. H. S. Saini
Warangal, India — Dr. T. Srinivas
Warangal, India — Dr. D. M. Vinod Kumar
Hyderabad, India — Dr. K. S. Chandragupta Mauryan

Contents

About the Editors

Dr. H. S. Saini is a Managing Director for Guru Nanak Institutions and obtained his Ph.D. in the field of Computer Science. He has over 22 years of experience at university/college level in teaching UG/PG students and has guided several B.Tech., M.Tech., and Ph.D. projects. He has published/presented more than 30 high-quality research papers in international and national journals and proceedings of international conferences. He is the editor for Journal of Innovations in Electrical and Electronics Engineering (JIEEE) published by Guru Nanak Publishers. He has two books to his credit. Dr. H. S. Saini is a lover of innovation and is an advisor for NBA/NAAC accreditation process to many institutions in India and abroad.

Dr. T. Srinivas, Dean, Department of Electronics & Communication Engineering, Kakatiya University, Warangal, obtained M.Tech. from IIT Dhanbad, and Ph.D. degree from Kyushu University, Japan. He was completed proficiency courses and diplomas from IISc Bangalore, IIT Kharagpur, CEDT Gorakhpur, and NRDC New Delhi. He worked as Scientist at NIRM, Government of India Research Institute, around two decades. He published over 142 research papers in various international and national journals and conferences. He is reviewer for International Journal of Measurements, Elsevier Publisher, and ISOI Journal. He obtained product patent of MBSC system and commercialized. He is regular reviewer to Indian and abroad IEEE conference papers as TPC member. He has successfully completed 15 industry-, DST-, and AICTE-sponsored research projects. He is author to a book entitled Real Time Systems for Coal Mine Applications. He has received several awards, honors and distinctions, International Bridge Fellowship, International JSPS Fellowship, International JSPS Medals, best paper awards, Gold Card NSL USA. He is Fellow of Institution of Electronics and Telecommunication Engineers and Fellow of Telangana Academy of Sciences. He is the advisory board member of IC, Cambridge University, UK. He was secretary to Instrument Society of India, Hyderabad, and EC member of IJAA. He is the life member of ISTE, BCSI, ISCA, and ISOI. His areas of research include real-time systems, wireless sensor networks/IOT, and cognitive radios.

Dr. D. M. Vinod Kumar joined at National Institute of Technology Warangal in 1981 as a faculty member. He was Head, Department of Electrical Engineering, during 2007–2009, and Dean (Academic) during 2009–2011. He was Chairman, Institution of Engineers (India) Warangal Local Chapter during 2012–2014. At present, he is a Professor of Electrical Engineering at National Institute of Technology, Warangal. He obtained his B.E. and M.Tech. degrees from Osmania University, Hyderabad, during 1979 and 1981, respectively. He earned his Ph.D. degree from IIT Kanpur in the year 1996. During 2002–2003, he was Post-Doctoral Fellow at Howard University, Washington, D.C., USA. He has published more than 100 papers in international journals and conferences. He is Fellow of Institution of Engineers (India) Kolkata and the life member of Systems Society of India (SSI). He is the member of Board of Studies of the Department of Electrical Engineering, Osmania University, Hyderabad, and JNTU, Hyderabad, Kakinada, and Anantapur. He delivered expert lectures on neural networks and fuzzy logic at various institutions. His areas of interest are power systems operation and control, power system stability and security, neural networks and fuzzy logic applications, flexible AC transmission systems, power system deregulation and restructuring and smart grid technologies, multi-objective evolutionary algorithm applications, and renewable energy systems.

Dr. K. S. Chandragupta Mauryan is working as a Professor in EEE and Assistant Dean R&D, Guru Nanak Institutions Technical Campus, Hyderabad. He has completed Ph.D. in Electrical Engineering from Anna University, Chennai, in the year 2015, M.E. in Power Systems Engineering from PSG College of Technology, Coimbatore, in the year 2004, and B.E. in Electrical and Electronics Engineering from Bharathiar University, Coimbatore, in the year 2001. He has also qualified the GATE 2001 Examination in Electrical and Electronics. He has published more than 30 technical papers in international and national journals. He has published 6 patents and filed 1 patent in Patent Office, India. He has presented more than 25 research papers in international and national conferences. He is the member of professional societies like IEEE, ISTE, ISRD, IRED, and IAENG. He is having 15 years of teaching and 11 years of research experience. His research interests are power systems optimization, smart grid technologies, soft computing applications, renewable energy sources, and electric vehicle.

Power Electronics

Power System Security Analysis Using FACTS Devices by Means of Intelligent and Hybrid Techniques Under Different Loading Conditions

S. Venkata Padmavathi, A. Jayalaxmi and Sarat Kumar Sahu

Abstract Power system security issue is a severe concern in restructured power market. In order to conserve the security of a system, flexible alternating current transmission system (FACTS) apparatus are one of the options. In this work, node voltage deviations and line apparent power flow factors are taken as the security indices and these are considered as objectives for security problems. The devices considered are thyristor-controlled series capacitors (TCSCs), static VAR compensators (SVCs), and unified power flow controllers (UPFCs). The main idea of this work is to compare distinct algorithms such as hybrid differential evolution (DEPSO) and fuzzy adaptive gravitational search algorithm (FAGSA) to attain the good location of the devices on IEEE 30 bus network with loading conditions.

Keywords DEPSO · FAGSA · FACTS · TCSC · SVC · UPFC

1 Introduction

Today's power network has become tortuous and less secure with increase of power demand. FACTS apparatus can augment power system transfer capacity and flexible line flow control [1]. These devices play a major task in power system security and can control the network parameters to influence the line power flows and voltages [2–4]. There are various types of FACTS controllers: SVC [5, 6], TCSC [7], UPFC [8], etc.

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H. S. Saini et al. (eds.), *Innovations in Electrical and Electronics Engineering*, Lecture Notes in Electrical Engineering 626,
https://doi.org/10.1007/978-981-15-2256-7_1

Evolutionary and fuzzy adaptive methodologies are well-liked in current years. Some reputable techniques like DE were utilized to allocate the FACTS and improve the security [9], and PSO was introduced by 'John Kennedy and Eberhart' [10]. It is important to know, the better location for FACTS since their cost and to evade needless transmission loss, in [11] GA-based optimization technique was implemented to get the fine placements and sizing of the FACTS to augment the network loadability, in [12] multiobjective optimization process was utilized to get the better placement of FACTS to optimize the cost, line losses and loadability. In [13], GA to ask for the good placement of multi-type FACTS in a network; in [14], genetic algorithm is exercised to advance power system security; in [15, 16], hybrid differential evolution is presented to resolve the power flow trouble and system security; in [17, 18], GSA technique is implemented; in [19], FAGSA is applied to resolve bidding problem; in [20], reactive power planning is presented.

In this work, the main intention is to examine the various algorithms such as DEPSO and FAGSA to set the good location of FACTS and to get the lowest cost of FACTS apparatus, minimum loss and to improve the electrical power system security, which is obtained by bringing down the security index. These algorithms are tested using the standard IEEE 30 bus system. It is noticed that power system security is augmented by minimizing the system loss and security index.

2 FACTS Device Modelling

The three FACTS utilized in this work are TCSC, SVC, and UPFC models [1, 5, 6, 12], and constraints are considered as

$$\text{(i)} -0.8X_L \leq X_{\text{TCSC}} \leq 0.2X_L \text{P.u} \tag{1}$$

$$\begin{aligned} &\text{(ii)} \ -100\,\text{MVAR} \leq Q_{\text{SVC}} \leq 100\text{MVAR} \\ &\text{(iii) both (1) and (2) for UPFC} \end{aligned} \tag{2}$$

where X_{TCSC} is reactance [7] added to the transmission line by employing TCSC, X_L is the reactance of line, and Q_{SVC} is the reactive power interjected [5, 6] at the node. The UPFC is used to control both parameters [8, 11].

3 Power System Security

The main intention of the security [2–4], [9] is to conserve the profile of voltage and line power flow within the limits. These are modelled as voltage and line apparent power security indices 'J_v' and 'J_s' [9]

$$J_S = \sum_{i}^{n} \sum_{i,j=1}^{n} W_i \left(\frac{S_{ij}}{S_{ij}^{\max}} \right)^2 \tag{3}$$

$$J_V = \sum_{i}^{n} W_i \left| V_i - V_{\mathrm{ref},i} \right|^2 \tag{4}$$

where i, j: node numbers

W_i	Weighing factor and taken as 1
S_{ij}	Apparent power in the $i - j$ line
$S_{ij}^{\max}$	Apparent power limit in line $i - j$
$V_{\mathrm{ref},i}$	Nominal voltage.

4 Problem Formulation

The proposed work is to diminish the installation cost of FACTS, loss, and security indices. By combining all, objective (Objfn) or fitness function is created.

$$\mathrm{Objfn} = F = a_1(J_S) + a_2(J_v) + a_3(\mathrm{Total\,Investment\,Cost}) + a_4(\mathrm{Losses}) \tag{5}$$

The cost functions in (US$/KVAR) of devices are expressed in Eqs. (6)–(8).
For TCSC

$$C_{\mathrm{TCSC}} = 0.0015S^2 - 0.713S + 153.75 \tag{6}$$

For SVC

$$C_{\mathrm{SVC}} = 0.0003S^2 - 0.3051S + 127.38 \tag{7}$$

For UPFC

$$C_{\mathrm{UPFC}} = 0.0003S^2 - 0.2691S + 188. \tag{8}$$

where S is the operating range of the FACTS in MVAR [20, 21]. The coefficients a_1–a_4 will be equal to 0.25.

5 Overview of Algorithms and Its Implementation

5.1 Hybrid Differential Evolution (DEPSO)

In the DEPSO, one-to-one competition is initiated which will provide rapid convergence swiftness towards optimum. It uses fewer populations in the evolutionary procedure to get the global result [15, 16]. To get rid of the problems in DE and PSO technique [22, 23] and to get the advantages of both, the DEPSO method is developed.

The procedure is as follows:

- First produce random values of population (*N*).This is taken as parent vector.
- Determine the fitness function F_1 (*i*) for each of the particles in the parent vector, for $i = 1, 2, 3, \ldots, N$.
- Now, do the operations like selection, crossover, and mutation. The consequent vector is the target vector.
- Find the fitness value F_2 (*i*) for each agent in the target vector.
- Obtain the *G*best up to this iteration.
- Evaluate each particle or agent velocity in the parent vector using these Pbest and Gbest values.
- By using the PSO algorithm, update the positions the particles.
- By using these values, evaluate the fitness value F_3 (*i*) and compare the three fitness values.
- Now, these selected set of particles become parent vector for subsequent iteration.

5.2 Fuzzy Adaptive Gravitational Search Algorithm (FAGSA)

It is a good method for controlling the parameter and to overcome the problems of GSA [19, 24], which is used to tune the 'gravitational constant (*G*)' using 'IF/THEN' rules of fuzzy. Proper selection of '*G*' provides a brace between the global and local exploration and exploitation [8, 19]. The inputs for FIS are the current best performance evaluation as 'normalized fitness value (NFV)' and the recent '*G*'. The outputs are 'ΔG'. The membership functions are considered as triangular.

$$\text{NFV} = \frac{\text{objfn} - \text{objfn}_{\text{min}}}{\text{objfn}_{\text{max}} - \text{objfn}_{\text{min}}} \tag{9}$$

Here, the poorer value of NFV gives the superior result. Objfn is calculated from Eq. (5). The limit of ‘G’ is considered between 0.4 and 1.0, and NFV is considered between 0 and 1.0 and ‘ΔG’ range in between −0.1 and +0.1.

$$G^{t+1} = G^t + \Delta G \tag{10}$$

5.3 Initialization

Using the algorithms, the primary particles’ population is produced haphazardly between the prearranged limits and calculated the fitness function. The FACTS variables are their placement and setting. By using these values, the objective function shown in Eq. (5) is calculated.

6 Results and Discussion

The functioning of these algorithms is examined on the IEEE-30 [25] bus, and the solutions are obtained. The FACTS apparatus setting, cost, security indices, loss were found by means of these algorithms. The FACTS are installed in a particular location to lessen the loadings of active and reactive powers by regulating the powers in other directions, and the better locations are obtained by these algorithms. This is observed from security indices J_s, J_v which are reduced by using these optimization techniques with loading conditions.

Fuzzy rules, PSO, DE, and GSA parameters are shown in Tables 1, 2, 3, and 4. The security objectives for 40% light load, 60% over load and device location, and ratings are given in Tables 5, 6, 7, and 8 and observed that the security indices and loss are lessened, and hence, security has been progressed.

Table 1 Fuzzy rules

Rule no.	NFV	G	ΔG
1	S	S	ZE
2	S	M	NE
3	S	L	NE
4	M	S	PE
5	M	M	ZE
6	M	L	NE
7	L	S	PE
8	L	M	ZE
9	L	L	NE

Table 2 Parameters of PSO

C_1, C_2	1.5
W_{max}	0.9
W_{min}	0.4
No. of swarm being	50
No. of iterations	100

Table 3 DE parameters

NP	*D*	*F*	CR	Iterations
30	2	1.2	0.5	100

Table 4 GSA parameters

NP	G_o	Iterations
30	100	100

Table 5 Security objectives under 40% light load at bus 7

	J_S			J_V			Loss			Cost ($) * 10^6	
Techniques	Base case	DEPSO	FA GSA	Base case	DEPSO	FA GSA	Base case	DEPSO	FA GSA	DEPSO	FA GSA
Without FACTS	9.7	–	–	0.0263	–	–	15.7	–	–	–	–
TCSC	–	9.28	9.23	–	0.0215	0.0205	–	15.21	15.14	2.66613	2.9784
SVC	–	9.46	9.42	–	0.0154	0.0148	–	15.24	15.19	1.9376	1.5212
UPFC	–	8.98	8.94	–	0.0143	0.0140	–	15.09	15.02	4.3664	2.7637

Table 6 FACTS placement and the ratings

	Line/bus		Rating	
Techniques	DEPSO	FA GSA	DEPSO	FA GSA
TCSC (X_{tcsc})	2–4	3–4	0.0421	0.0210
SVC (Q_{svc})	21	8	15.8	12.3
UPFC (X_{tcsc} & Q_{svc})	2–4	6–8	0.0236	−0.054
			13	9.8

Table 7 Security objectives under 60% over load at bus 7

	J_S			J_V			Loss			Cost($) * 10^6	
Techniques	Base case	DEPSO	FA GSA	Base case	DEPSO	FA GSA	Base Case	DEPSO	FA GSA	DEPSO	FA GSA
Without FACTS	11.3	–	–	0.0259	–	–	19.7	–	–	–	–
TCSC	–	10.65	10.56	–	0.0192	0.0186	–	19.18	19.14	4.2953	3.9305
SVC	–	10.79	10.74	–	0.0191	0.0169	–	19.24	19.20	2.6350	2.3701
UPFC	–	10.54	10.48	–	0.0181	0.0172	–	18.76	18.69	6.9996	7.5196