International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 05 | May -2020 ISSN: 2582-3930

Optimal Location and Coordinated Control of FACTS Controllers in Power Systems

AKASH GUPTA

Abstract:-This paper presents the review on methods for optimal location and coordinated control of FACTS controllers such as TCSC, SVC, STATCOM, SSSC, D-STATCOM, UPFC, IPFC, DVR, GUPFC, GIPFC and HPFC in power systems from different power system performance viewpoint such as minimization of real and reactive power loss, improvement of voltage profile, minimization of environmental pollutions, and minimization of short circuit current capacity etc. This paper also presents the current status on optimal placement and coordinated control of FACTS controllers in power systems. This article is very much useful for scientific persons, industrial persons and researchers in field of optimal placement and coordinated control of FACTS controllers in power systems.

Keywords:-FACTS, FACTS Controllers, Power Systems, Power Flow Analysis, Optimal Location and Coordination Control.

Nomenclature

SVC	Static Var Compensator
TCSC	Thyristor Controlled Series Capacitor
STATCOM	Static Compensator
SSSC	Series- Sub Synchronous Compensator
D-STATCOM	Distributed-STATCOM
UPFC	Unified Power Flow Controllers
IPFC	Interlink Power Flow Controller
DVR	Dynamic Voltage Restorer
GUPFC	Generalized Unified Power Flow Controller
GIPFC	Generalized Interlink Power Flow Controller
HPFC	Hybrid Power Flow Controller
VSC	Variable Series Compensation
PSS	Power System Stabilizer
CDO	Coordinated Optimal
PID	Proportional Integral Derivative
SPS	Static Phase Shifter

I. INTRODUCTION

In power system networks, various FACTS controllers are incorporated from different power system analysis such as minimization of real and reactive power loss in minimization of power system oscillation, maximization of bus voltage, maximization of variable power transfer capacity, maximization of loadability of system, enhancement of power system stability, enhancement of power system reliability etc.

The varying FACTS controllers are incorporated in system networks from two important issue such as optimal placement and properly coordinated FACTS controllers for better power system performance. The various FACTS controllers are optimally placed but not properly coordinated that's why the voltage and current interaction problem arises which is harmful for FACTS controllers and it may be dangerous. So the properly coordinated control is also an important issue for incorporation of FACTS controllers in power system networks.

A. Types of FACTS controllers:

1) On the basis of connections:-FACTS controllers are broadly classified in four categories on basis of connection diagrams are as follows:
   Series connected FACTS controllers (*e.g.*TCSC,TCPAR and SSSC); shunt connected FACTS controllers (e.g. SVC, STSTCOM and D-STATCOM); series-Series connected FACTS controllers (*e.g.* IPFC and GIPFC); shunt-Series connected FACTS controllers (*e.g.* GIPFC, GUPFC and HPFC).

2) On the basis of converter topology used:- The FACTS controllers are classified into two categories on the basis of converter topologies as follow-
   Thyristor controller based (*e.g.*TCSC, TC-PAR and SVC)
   VSI based (*e.g.*SSSC, STATCOM, UPFC, GUPFC, D-STATCOM, IPFC, GIPFC and HPFC)

3) On the basis of generation:- the FACTS controllers are classified on the basis of generation as follow:-
   First generation (*e.g.* TCSC, SVC and TC-PAR)
   Second generation (*e.g.* SSSC and STATCOM)
   Third generation (*e.g.* IPFC, GIPFC, UPFC,GUPFC,HPFC and D-STATCOM)

[B]. Optimal Location of FACTS Controllers Variables

The following considerations of variables are chosen for optimal location of FACTS controllers in PSNs are:-

I. Location & size
II. Type, location & size
III. Size, location & type
IV. Number, type, location & size
V. Number, location & size
VI. Number, type & location etc.

[C]. Coordinated control of FACTS Controllers

The following considerations of variables are chosen for coordinated control of the FACTS controllers are:-

I. Voltage interaction
II. Current interaction
III. Frequency interaction
IV. Voltage & current interaction
V. Voltage, current & frequency interaction
VI. Voltage & frequency interaction etc.

This paper is organized as follows:-

Section II: - Discuss the mathematical modeling of different FACTS controllersSection III: - Discuss a review on optimal placement and coordinated control of FACTS controllers. Section IV: - Presented the summary of paper. Section V: - Presented the conclusions and future scope of the work.

II. A TAXONOMICAL REVIEW

Table 1:-A taxonomical review onoptimal placement and properly coordinated control of FACTS controllers in power system networks

Ref.	Authors	Proposed Methods	FACTS Controllers	Parameter enhance	Test System	Future Scope
[1]	K. Vijayakumar et al.	Genetic Algorithm	TCSC and UPFC	Overall system cost	IEEE- 9 Bus	Multi objective task
[2]	Imran Khan et al.	Sensitivity	UPFC	Security	IEEE-14 Bus	Realistic load models
[3]	Kumar, B.K. et al.	Line Index	TCSC	Line power flow control	New England 39-bus system.	Hybrid techniques
[4]	A.R. Phadke et al.	Genetic Algorithm	Shunt FACTS	Voltage stability	IEEE-14 Bus &IEEE-57 Bus	Latest FACTS controllers such as HPFC
[5]	Leung	Genetic Algorithm	Multiple-type FACTS	Cost effectiveness	4-BUS	Latest FACTS controllers such as HPFC
[6]	B. Kalyan Kumar et al.	Controllability Index	SVR, TCSC and UPFC	Damping out oscillations.	New England 39-Bus system and 16-machine, 68-bus system	Realistic load models
[7]	Del Rosso et al.	Novel hierarchical control	TCSC	Stability Improvement	New England 39-bus system.	Hybrid techniques
[8]	Glanzmann G. at al.	Supervisory controller based on optimal power flow (OPF)	SVC, TCSC and TCPST	Avoid congestion	4-BUS	Latest FACTS controllers such as HPFC
[9]	Bindeshwar Singh et al.	Phasor Measurement Units (PMUs)	Multiple-type FACTS	Advanced power system monitoring	IEEE-14 Bus &IEEE-57 Bus	Realistic load models
[10]	S.-H. Song et al.	Install and operate FACTS devices properly	Shunt controllers, series controllers and combined series-shunt controllers such UPFC	Steady-state security	IEEE 57-Bus	Multi objective task
[11]	Yu, T. et al.	Application of Projective Controls	TCSC and SVC	Dynamic performance of a power system	Single Machine to Infinite Bus System	Hybrid techniques
[12]	Bindeshwar Singh et al.	Optimally placed Distributed Generation (DG)	Multiple-type FACTS	Enhancement of different performance parameters	IEEE 57-Bus	Hybrid techniques
[13]	Li. G. et al.	Digital simulation	VSC	Power system damping	PSCAD/EMTDC software package	Realistic load models
[14]	M.W. Mustafa at el.	Residue factor	SVC	Improve voltage and reactive power conditions	25 Bus of south Malaysian power system	Hybrid techniques
[15]	Bindeshwar Singh et al.	Techniques for coordination	Multiple-type FACTS	Co-ordination control between FACTS controllers	IEEE 14-bus	Multi objective task
[16]	Talebi, N. et al.	Steady State Models	SVC and TCSC	Voltage Collapse	IEEE 14 Bus test system	Latest FACTS controllers such as

						HPFC
[17]	Zarghami M. et al.	Finding an equivalent reduced affine nonlinear system	Shunt controllers, series controllers and combined series-shunt controllers	Stability	68 bus, 16 generator system of the New England/New York network.	Multi objective task
[18]	H. Shayeghi et al.	Particle swarm optimization (PSO) technique	TCSC and PSS	Dynamic stability	Multi-machine power system	Latest FACTS controllers such as HPFC
[19]	Guojie Li et al.	Damp inter-area oscillations	CDO and TCSC	Damping during large disturbances	Two-machine power system through real-time digital simulation studies using a PSCAD/RTDS	Realistic load models
[20]	Jordehi A.R. et al.	Evolution Strategies (ES)	SVC, TCSC and UPFC	Maximize the system loadability	IEEE 30-Bus test system	Hybrid techniques
[21]	Yashar Hashemi et al.	Particle Swarm Optimization Algorithm	PSS and UPFC	Damping of power system oscillations.	IEEE 14-bus	Latest FACTS controllers such as HPFC
[22]	M. K. Verma et al.	SVC placement computes sensitivity of system loading factor with respect to reactive power generation	SVAR and SVC	Voltage security	75-Bus Indian system with respect to enhancement of the static as well as dynamic voltage stability margins.	Multi objective task
[23]	Abdelsalam H.A et al.	Steady state injection model of UPFC	UPFC	Identify the optimal location of the unified power flow controller UPFC in electrical power systems	IEEE 14-bus Test System	Realistic load models
[24]	Baghaee, H.R et al.	Genetic Algorithm (GA)	Multiple-type FACTS	Stability	IEEE 30-Bus power system	Latest FACTS controllers such as HPFC
[25]	E.S. Ali et al.	Bacteria Foraging Optimization Algorithm (BFOA) based Thyristor Controlled Series Capacitor (BFTCSC)	TCSC	Superior efficiency	IEEE 57-Bus	Multi objective task
[26]	Yong Li et al.	Robust Control Theory	SVC and TCSC	Stability	16-Machine 5-area system	Hybrid techniques
[27]	Mahdad, B et al.	Fuzzy Logic Theory	SVC and STATCOM	Improvement of index power quality	IEEE 57-Bus	Realistic load models
[28]	M.M. Farsangi et al.	A mixed H_2/H_∞ with regional pole placement	SVC, SSSC and UPFC	Accurate specification of the desirable closed-loop behaviour	IEEE 57-Bus	Latest FACTS controllers such as HPFC
[29]	R. Benabid et al.	Particle Swarm Optimization (PSO)	TCSC and SVC	Multi-objective optimization	IEEE 30-bus and realistic Algerian 114-Bus power system	Multi objective task
[30]	N. Magaji et al.	Residue Factor	UPFC	Increase transmission capacity	TNB 25 Bus system of south Malaysian network and New England 39 bus system	Multi objective task
[31]	Baghaee, H.R et al.	Genetic Algorithm	Multi-type FACTS	Allocation of FACTS devices	IEEE 30 Bus power system	Multi objective task
[32]	Joorabian, M. et al.	LMP Based	TCSC	Secure operation	IEEE 14-Bus and IEEE 30-Bus test systems	Latest FACTS controllers such as HPFC
[33]	José A. Domínguez-Navarro et al.	Evolutionary Strategy	Multiple-type FACTS	Study of power systems	IEEE 57-Bus	

[34]	S. Panda et al.	Particle Swarm Optimization (PSO)	PSS and TCSC	Stability	Algerian 114-Bus power system	Realistic load models
[35]	C. T. Vinay Kumar et al.	Fuzzy Technique	TCSC and UPFC	Optimal location for FACTS devices	IEEE 57-Bus	Hybrid techniques
[36]	So, P.L. et al.	Coordinated Control	TCSC and SVC	Stability	2-Area interconnected 4-machine system	Latest FACTS controllers such as HPFC
[37]	Candelo, J.E et al.	FACTS Controllers	Multiple-type FACTS	Voltage Stability	IEEE 30-Bus power system	Latest FACTS controllers such as HPFC
[38]	Shakib, A.D. et al.	Sensitivity Index	Shunt FACTS	Improve Security	IEEE 57-Bus system.	Hybrid techniques
[39]	Benabid, R. et al.	Particle Swarm Optimization (PSO)	TCSC and SVC	Multiobjective Optimization	Two and three objective functions for various FACTS combinations	Hybrid techniques
[40]	P. Ramasubramanian et at.	Evolutionary Programming (EP)	TCSC	Optimal Power Flow (OPF) problem	IEEE 14 Bus system	Multi objective task
[41]	Mandala, M. et al.	Real power performance index	TCSC	Optimal Location	Algerian 114-Bus power system	Multi objective task
[42]	Adepoju, G. A. et al.	Mathematical modeling	STATCOM	Power System Analysis		5-bus using FACTSPF
[43]	N. Mithulananthan et al.	Bifurcation Theory	SVC and PSS	Effectiveness of these controllers	16-Bus test system	Latest FACTS controllers such as HPFC
[44]	Zuwei Yu et al.	Multiple Time Periods	Multiple-type FACTS	Optimal Placement	46-Machine power system	Latest FACTS controllers such as HPFC
[45]	Gupta, S. et al.	Semiconductor Technology Development	Multiple-type FACTS	Voltage Stability	IEEE 118-bus	Realistic load models
[46]	Juan M. Ramírez et al.	Coordinate Stabilizers	TCSC and UPFC	Operational Dynamic Stability Margin	46-Machine power system	Multi objective task
[47]	A.R. Messina et al.	Modified modal power flow oscillation flow	SVR	Optimal Locations For New Devices	46-Machine, 190-bus reduced-Order Equivalent model of the Mexican interconnected system	Realistic load models
[48]	Shen, J et al.	H Infinity Norm	PSS and TCSC	Determines the location of controllers	IEEE-30 Bus	Hybrid techniques
[49]	R.Mohamad Idris et al.	Bees Algorithm	SVC, UPFC and TCSC	Optimal Allocation of FACTS Devices	IEEE-9 Bus test system and IEEE-118 Bus test system	Latest FACTS controllers such as HPFC
[50]	A. Hernandez1 et al.	Optimization Methods	Multiple-type FACTS	FACTS Location	IEEE-30 Bus	Latest FACTS controllers such as HPFC
[51]	Ramirez, J.M et al.	Closed-loop Characteristic Polynomial	TCSC and UPFC	Power System Damping	Three-machine power system	
[52]	Kaewniyompanit, S. et al.	Microgenetic Algorithm (μGA)	Multiple-type FACTS	Power System Characteristics	Single machine infinite bus	Hybrid techniques
[53]	B. Bhattacharyya et al.	Differential Evolution (DE) based and Particle swarm optimization (PSO)	Multiple-type FACTS	Improved Power transfer Capacity	IEEE 30-Bus system	Multi objective task
[54]	Berizzi, A. et al.	Genetic Algorithm	TCSC and SVC	Efficiency	Suitable Test Systems	Realistic load models
[55]	Ali Darvish Falehi et al.	Generic Algorithm	SVC, PID and PSS	System Stability	Multimachine Power System	Latest FACTS controllers such as HPFC

[56]	E. S. Ali et al.	Bacteria Foraging Optimization Algorithm (BFOA)	SVC	Damping Performance	Multimachine Power System	Hybrid techniques
[57]	Lucio Ippolito et al.	Genetic Algorithm	UPFC	Network Operation	IEEE 30-Bus Power system	Hybrid techniques
[58]	Ilea, V. et al.	Modal Sensitivity Analysis	PSS	Optimal Location of FACTS	IEEE-9 Bus test system	Latest FACTS controllers such as HPFC
[59]	J. Aghaei et al.	Convergence of The Newton-Raphson	TCSC and SVC	Voltage Security Margin	IEEE-5 Bus	Multi objective task
[60]	Wang, Y. rt al.	Variable-Structure Control Theory	Series Capacitor (SC) and Braking Resistor	Transient Stability Control	Single Machine Infinite-Bus (SMIB) System	Hybrid techniques
[61]	Juan M. Raminrez et al.	Co-Ordinate Stabilizer	TCSC and UPFC	Dynamic stability	IEEE-5 Bus	Realistic load models
[62]	C.M. Yam et al.	Singular Value Decomposition Based Controller	UPFC	Dynamic interaction	IEEE-30 Bus	Latest FACTS controllers such as HPFC
[63]	P.K. Dash et al.	Artificial Neural Network	UPFC	Trip boundries	Multi-machine power system	Multi objective task
[64]	Y.L. Abdel-Magid et al.	Genetic Algorithm	TCSC, TCPST, TCVR and SVC	the location of the devices, their types and their values	IEEE-118Bus	Realistic load models
[65]	N.P. Padhy et al.	Newton–Raphson Power Flow Algorithm	GUPFC, TCSC and UPFC	power transfer	IEEE-30 Bus	Latest FACTS controllers such as HPFC
[66]	M.A. Adibo et al.	Genetic Algorithm	FACTS devices	Stability	IEEE 57-Bus	Multi objective task
[67]	Y.L. Abdel-Magid et al.	Real-Coded Genetic Algorithm	TCSC	Stability	Multi-machine power system	Hybrid techniques
[68]	Bindeshwar Singh et al.	FACTS Controller	TCSC, SVC, SSSC, STATCOM, UPFC, IPFC	Stability	IEEE-5 Bus	Multi objective task
[69]	Naresh Acharya et al.	Co-ordinate Stabilizers	UPFC	Dynamic stability	IEEE-14 Bus	Latest FACTS controllers such as HPFC
[70]	K.S. Verma et al.	Suitable Location For UPFC	UPFC	Sensitivity	IEEE-14 Bus	Hybrid techniques
[71]	Gabriela Glanzmann	FACTS	SVC, STATCOM, TCR, TSR,TSC, TSSC, TCSC, GCSC, SSSC, UPFC, IPFC	Transfer capability	IEEE-9 Bus test system	Multi objective task
[72]	Bindeshwar Singh et al.	Application Of FACTS Controller	TCR, TSC, TCSC, SVC, TC-PAR, SSSC, STATCOM, D-STATCOM, UPFC, GUPFC, IFPC, GIPFC, HPFC, SMES, BESS, TCBR, TSSR	Performance parameters	IEEE-5 Bus	Multi objective task
[73]	B.A. Renz et al.	Inez Installation	UPFC, SSSC	Optimization of power flow	IEEE-9 Bus test system	Hybrid techniques
[74]	Arthit Sode-Yome et al.	Alleviate Voltage Control	SVC, STATCOM	Stability	IEEE-14 Bus	Latest FACTS controllers such as HPFC
[75]	N. Mithulananthan et al.	Power System Stabilizers	SVC, STATCOM	Inertia and oscillation	IEEE-145 Bus	Hybrid techniques
[76]	Mr.P.S.Chindhi et al.	Optimization Technique	FACTS Devices	Stability	Multi-machine power system	Latest FACTS controllers such as HPFC
[77]	Salim. Haddad et al.	Simulation By Matlab	UPFC	Modelling	IEEE-9 Bus test system	Multi objective task
[78]	S. Surendar Reddy et al.	multi-objective genetic algorithm	SVC, TCSC	Line impedance, terminal voltage and angle	Multi-machine power system	Multi objective task
[79]	Gregory Reed et al.	FACTS Controller	STATCOM	Power transmisson control	IEEE-5 Bus	Latest FACTS controllers such as HPFC

[80]	Naresh Acharya et al.	FACTS installation	TCSC, STATCOM, SVC, UPFC	Stability	IEEE 57-Bus	Multi objective task
[81]	Bindeshwar Singh et al.	Mitigation Of Power Quality	STATCOM, DSTATCOM	Performance parameter	IEEE-5 Bus	Realistic load models
[82]	M. A. Abido	FACTS damping controllers	SVC, TCSC, TCPS, STATCOM, SSSC, UPFC, IPFC	Stability	IEEE-9 Bus test system	Latest FACTS controllers such as HPFC
[83]	Jun-Yong Liu et al.	Power Injection Model	UPFC	Voltage magnitude, line current	28-node	Multi objective task
[84]	Guang Ya Yang et al.	linear programming	TCSC	Loadability	Multi-machine power system	Multi objective task
[85]	A.H.M.A. Rahim et al.	Excitation Control	SVC	Stability	46-Machine power system	Realistic load models
[86]	Sidhartha Panda et al.	Simulation by MATLAB	TCSC, STATCOM and UPFC	Modelling	IEEE 57-Bus	Multi objective task
[87]	D.J. Gotham et al.	Wheeling And Interchange Power Flow Control	FACTS Devices	Modelling	IEEE 57-Bus	Realistic load models
[88]	Michael J. Gibbard et al.	Power System Stabilizer	FACTS Devices	Damping	Multi-machine power system	Latest FACTS controllers such as HPFC
[89]	L. Bahiense et al.	mixed integer linear disjunctive formulation	none	Transmission planning	IEEE-9 Bus test system	Realistic load models
[90]	Liangzhong Yao et al.	Congestion management	SSSC	Transfer Capability	IEEE-30 Bus	Realistic load models
[91]	Yong Li et al.	Robust CO-ordinated approach	SVC, TCSC	Inertia And Oscillation	Single Machine Infinite-Bus (SMIB) System	Latest FACTS controllers such as HPFC
[92]	S. M. Abd-Elazim et al.	Hybrid Algorithm	TCSC	Damping Oscillations	IEEE-9 Bus test system	Realistic load models
[93]	Sandeep Gupta et al.	FACTS Installations	IPFC, SVC, STATCOM, SSSC, TCSC, TCPS, UPFC	Voltage Stability	Single Machine Infinite-Bus (SMIB) System	Multi objective task
[94]	Mark Ndubuka Nwohu et al.	Simulation	SVC	Voltage Stability	IEEE 57-Bus	Latest FACTS controllers such as HPFC
[95]	R. Nelson et al.	Transient Stability Simulations	SVC, TCSC, STATCOM, UPFC	Stability	IEEE-5 Bus	Multi objective task
[96]	S. K. Tso et al.	Nonlinear Design Technique	SVC, TCSC	Overall Performance	Single Machine Infinite-Bus (SMIB) System	Realistic load models
[97]	L. Rouco	Electromechanical Oscillations	none	Sensitivity	IEEE-9 Bus test system	Multi objective task
[98]	A. R. Messina et al.	Decentralised Control Theory	FACTS Devices	Inter-Area Oscillations	IEEE 57-Bus	Latest FACTS controllers such as HPFC
[99]	G. N. Taranto et al.	H∞-Optimisation Technique	SVC, TCSC	Inertia	Single Machine Infinite-Bus (SMIB) System	Multi objective task
[100]	Q. Yu et al.	Cascade Multilevel Configuration	STATCOM	Control	IEEE 57-Bus	Realistic load models
[101]	J. Paserba	FACTS Installations	FACTS Devices	Dynamic Performance	46-Machine power system	Realistic load models
[102]	M. M. Farsangi et al.	H∞ Loop-Shaping Design	STATCOM, SPFC and UPFC	Robust Control	IEEE-9 Bus test system	Multi objective task
[103]	S. Arabi et al.	Small-Signal Stability Analysis	SVC	Stability	IEEE 57-Bus	Latest FACTS controllers such as HPFC
[104]	K.Matsuno et al.	FACTS Installations	SVC, STATCOM, VSPS	Transfer Capability	46-Machine power system	Multi objective task
[105]	D. J. Hanson et al.	Novel Chain-Circuit Topology	SVC, STATCOM	Efficiency and Security	IEEE-9 Bus test system	Multi objective task
[106]	L. Cong et al.	Feedback Linearization Technique And Robust Control Theory	SVC	Transient Stability And Voltage Regulation	Single Machine Infinite-Bus (SMIB) System	Realistic load models

[107]	H. F. Wang et al.	Phillips-Heffron Model	SVC, CSC, TCPS	Power System Oscillation Stability	IEEE 57-Bus	Latest FACTS controllers such as HPFC
[108]	E. Acha et al.	Newton-Raphson Load Flow	SVC	Voltage Control	Single Machine Infinite-Bus (SMIB) System	Multi objective task
[109]	T. S. Chung et al.	Hybrid GA Approach	FACTS Devices	Power Flow	IEEE-9 Bus test system	Latest FACTS controllers such as HPFC
[110]	Ning Yang et al.	Residue Method	TCSC	Impedance	IEEE 14-bus	Realistic load models
[111]	B. Chaudhuri et al.	H∞ Control	SVC, CSC, CPS	Inter-Area Mode Damping	IEEE 14-bus	Hybrid techniques
[112]	A. Berizzi et al.	Congestion Management	FACTS Devices	Power Flow	IEEE 57-Bus	Hybrid techniques
[113]	W. Shao et al.	Linear Programming (LP) Based Optimal Power Flow (OPF) Algorithm	FACTS Devices	Sensitivity	IEEE-9 Bus test system	Realistic load models
[114]	A. M. Kulkarni et al.	Optimal Control	TCSC and SSSC	Frequency Oscillations	IEEE 57-Bus	Multi objective task
[115]	R. M. Hamouda et al.	Modal Speeds	SVC	Oscillation	46-Machine power system	Latest FACTS controllers such as HPFC
[116]	L. Fan et al.	Residue-Based Indices	TCSC	Oscillation		Realistic load models
[117]	Y. Ye et al.	Power Converter Modules	UPFC, IPFC	Power Flow Control	IEEE 57-Bus	Latest FACTS controllers such as HPFC
[118]	P. Duvoor et al.	Matlab/Simulink	FACTS Devices	Overall system cost	IEEE-9 Bus	Realistic load models
[119]	P. Paterni	Genetic Algorithm	Series FACTS such as series capacitors or phase shifters	Increased loadability and reduced cost of production	IEEE-9 Bus test system	Realistic load models
[120]	E. J. de Oliveira	Allocation and transmission pricing	Installation of FACTS devices	minimize the operational costs caused by an overloaded transmission system i	IEEE-14 Bus	Hybrid techniques
[121]	Sidhartha Panda et al.	Mid-Point location	SVC	Transient stability	IEEE-9 Bus test system	Latest FACTS controllers such as HPFC
[122]	Mahmoud H. M et al.	Continuation power flow	SVC	stability and maximum loadability	IEEE-14 Bus	Realistic load models
[123]	Claudio A. Caiiizares	Voltage collapse	TCSC	system loadability	IEEE 118-bus	Latest FACTS controllers such as HPFC
[124]	E. A. Leonidaki et al.	Decision trees	TCSC	loading margin	Single Machine Infinite-Bus (SMIB) System	Multi objective task
[125]	Roberto Mínguez et al.	nonlinear programming	SVC	loading margin	IEEE 57-Bus	Realistic load models
[126]	Ranjit Kumar Bindal et al.	Control of phase angle	SVC	transmission system availability	IEEE-9 Bus test system	Latest FACTS controllers such as HPFC
[127]	Cai, L.J et al.	Genetic algorithm	UPFC	Overall system cost		Realistic load models
[128]	M. Saravanan et al.	particle swarm optimization	TCSC	system loadability	IEEE 118-bus	Realistic load models
[129]	Wibowo, R.S et al.	large-scale optimization	SVC	Investment cost	IEEE 57-Bus	Latest FACTS controllers such as HPFC
[130]	Santiago-Luna et al.	evolutionary algorithm	TCSC	Loadability	IEEE 30-bus	Realistic load models

[131]	M. Basu et al.	differential evolution	TCSC	Processing	IEEE 30-bus	Multi objective task
[132]	Lashkar Ara et al.	general algebraic modeling system	UPFC	Economy	IEEE 14-bus	Realistic load models
[133]	El Metwally et al.	genetic algorithms	SVC	Economy	Single Machine Infinite-Bus (SMIB) System	Realistic load models
[134]	A. Lashkar Ara et al.	General Algebraic Modelling System	UPFC	Optimization	IEEE 30-bus	Latest FACTS controllers such as HPFC
[135]	Naresh Acharya et al.	LMP difference	TCSC	Minimizing congestion	IEEE 30-bus	Hybrid techniques
[136]	Sajad Rahimzadeh et al.	averaging technique	STATCOM	Managing congestion	IEEE 14-bus	Multi objective task
[137]	M. Gitizadeh et al.	goal attainment method	TCSC	Optimization	IEEE 14-bus	Realistic load models
[138]	Gerbex, S et al.	genetic algorithm	SVC	Loadability	IEEE 118-bus	Realistic load models
[139]	Ying Xiao et al.	power-injection model	TCSC	Operational flexibility	IEEE 1500-bus	Multi objective task
[140]	L. Gyugyi et al.	unified power flow	TCSC	Economy	IEEE 57-Bus	Latest FACTS controllers such as HPFC
[141]	Noroozian, M et al.	energy function method	UPFC	Effectiveness of control	IEEE-14 Bus	Multi objective task
[142]	Gotham, D.J et al.	Wheeling power flow control	TCSC	Flexibility	IEEE-9 Bus test system	Hybrid techniques
[143]	Hingorani, N.G et al.	Transmission system	TCSC	Efficiency	Single Machine Infinite-Bus (SMIB) System	Latest FACTS controllers such as HPFC
[144]	Minguez, R. et al.	Benders decomposition technique	SVC	optimal placement	IEEE-14 Bus	Realistic load models
[145]	Orfanogianni, T et al.	optimal power-flow algorithm	UPFC	Maximise power	IEEE 118-bus	Multi objective task
[146]	Li-Jun Cai et al.	parameter-constrained optimization algorithm	PSS	Efficiency	IEEE-9 Bus test system	Latest FACTS controllers such as HPFC
[147]	Wang Feng et al.	genetic algorithm	TCSC	Increase power transfer	IEEE 57-Bus	Realistic load models
[148]	Sidhartha Panda et al.	Particle Swarm Optimization Technique	SSSC	Improve transient stability	IEEE-14 Bus	Latest FACTS controllers such as HPFC
[149]	Bindeshwar singh et al.	Planning and protection	SSSC	Voltage profile	IEEE 118-bus	Multi objective task
[150]	Ashwani kumar et al.	controlling the power flows	TCSC	Lodability	IEEE 24-bus	Multi objective task
[151]	Vijayakumar Krishnasamy et al.	Genetic Algorithm	UPFC	Power flow	IEEE 9-bus	Multi objective task
[152]	Kiran kumar kuthadi et al.	Var compensation	TCSC	Voltage profile	IEEE 5-bus	Latest FACTS controllers such as HPFC
[153]	K. Lokanadham et al.	Genetic Algorithm	TCSC	Power Efficiency	IEEE 30	Multi objective task
[154]	E. S. Ali et al.	Genetic Algorithm	SVC	Suppressed Oscillation	IEEE-9 Bus test system	Hybrid techniques
[155]	Mahmoud H. M et al.	continuation power flow	SVC	Lodability	IEEE 14-bus	Hybrid techniques
[156]	S.M. AbdElazim et al.	Genetic Algorithm	SVC	Suppressed Oscillation	IEEE-9 Bus test system	Multi objective task
[157]	E.S. Ali et al.	coordinated controller	PSS	Stability	IEEE 57-Bus	Latest FACTS controllers such as HPFC
[158]	R.N.Patel et al.	Genetic algorithm	TCSC	Stability	IEEE-9 Bus test system	Hybrid techniques
[159]	A. Kazemiaet al.	Matlab	HFC	Improve Accuracy	IEEE-14 Bus	Hybrid techniques
[160]	A.Khairuddin et al.	Bees Algorithm	SVC	Available Transfer	IEEE 30	Multi objective task

				Capability ATC		
[161]	A. B.Bhattacharyya et al.	Genetic Algorithm	UPFC	Power transfer	IEEE 30-bus	Multi objective task
[162]	A. Karami et al.	reactive power management	IPFC	Voltage stability	IEEE 14-Bus	Latest FACTS controllers such as HPFC
[163]	Jigar S.Sardaet al.	improve system loadability	UPFC	loadability of the line	IEEE-30	
[164]	Nadarajah Mithulananthan	investment recovery of FACTSdevices	TCSC	investment recovery	Five bus	Latest FACTS controllers such as HPFC
[165]	A.A. Alabduljabbara, et al.	Technoeconomic contribution of FACTS devices	TCSC	economic value of the proposed methodology.	IEEE-14 Bus	Multi objective task
[166]	ZOU Zhenyu et al.	Multiobjective Evolutionary Algorithm	TCSC	coordination design problem of multiple FACTS controllers	IEEE-14 Bus	Hybrid techniques
[167]	Rusejla sadikovi´c et al.	Power Flow Control and Damping of Oscillations in Power Systems	UPFC	power system stability	IEEE 39	Latest FACTS controllers such as HPFC
[168]	Esmat Rashedi et al.	Gravitational Search Algorithm	SVC	transmission system voltage	IEEE-9 Bus test system	Realistic load models
[169]	Ren, H. et al.	Review of FACTS	Multiple-type FACTS	better and safer operation of the grid	IEEE 14-bus	Latest FACTS controllers such as HPFC
[170]	Yoke Lin Tan et al.	adaptive nonlinear coordinated	SPS	transient stability	IEEE 14-bus	Multi objective task
[171]	Padhy, N.P. et al.	genetic algorithms	TCSC	suboptimal solution for reactive power planning	IEEE 30	Hybrid techniques
[172]	Faried, S.O. et al.	Probabilistic technique	STATCOMs	maximum transmission capacity to be utilised.	IEEE-9 Bus test system	Hybrid techniques
[173]	Xinghao Fang et al.	Sensitivity	VSC	transfer capability and stability	1673bus	Latest FACTS controllers such as HPFC
[174]	Ja'fari, M. et al.	Shunt FACTS Devices	Multiple-type FACTS	system voltage stability	IEEE 14bus	Multi objective task
[175]	Wenjuan Zhang et al.	shunt dynamic Var source	STATCOM,	static and dynamic voltage stability	IEEE-9 Bus test system	Hybrid techniques
[176]	L.Rajalakshmi et al.	Locating Series FACTS Devices	TCSC	improved stability of the networ	IEEE 14	Hybrid techniques
[177]	Naresh Acharya et al.	Practical Installations and Benefits	SVC	distribute the electrical energy more economically	IEEE-14 Bus	Latest FACTS controllers such as HPFC
[178]	Ahmad rezaee jordehi et al.	Heuristic Methods	STATCOM	multi-objective optimization	IEEE 30	Multi objective task

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 05 | May -2020 ISSN: 2582-3930

II. DISCUSSES THE MATHEMATICAL MODELLING OF DIFFERENT FACTS CONTROLLERS

1. Fundamentals of SVC:

Static VAR Compensator (SVC) is a shunt connected FACTS controller whose main functionality is to regulate the voltage at a given bus by controlling its equivalent reactance. Basically it consists of a fixed capacitor (FC) and a thyristor controlled reactor (TCR). Generally they are two configurations of the SVC.

a) SVC total susceptance model. A changing susceptance Bsvc represents the fundamental frequency equivalent susceptance of all shunt modules making up the SVC as shown in Fig.
2(a).

b) SVC firing angle model. The equivalent reactance XSVC, which is function of a changing firing angle α, is made up of the parallel combination of a thyristor controlled reactor (TCR) equivalent admittance and a fixed capacitive reactance as shown in Fig. 2 (b). This model provides information on the SVC firing angle required to achieve a given level of compensation.

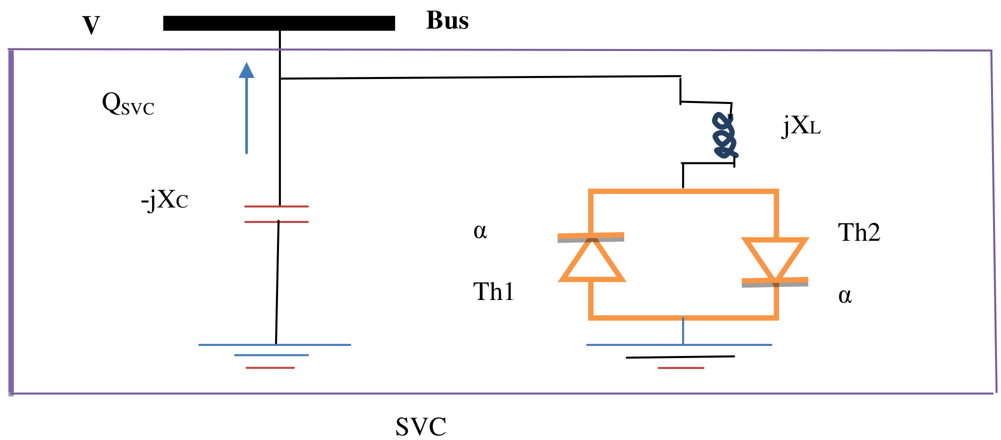

Fig.1 SVC firing angle model

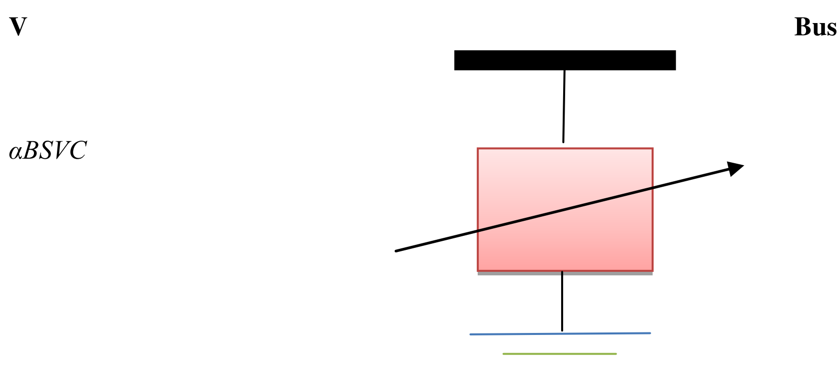

Fig.2 SVC total susceptance model

Figure 3 shows the steady-state and dynamic voltage-current characteristics of the SVC. In the active control range, current/susceptance and reactive power is varied to regulate voltage according to a slope (droop) characteristic. The slope value depends on the desired voltage regulation, the desired sharing of reactive power production between various sources, and other needs of the system. The slope is typically1-5%. At the capacitive limit, the SVC becomes a shunt capacitor. At the inductive limit, the SVC becomes a shunt reactor (the current or reactive power may also be limited)

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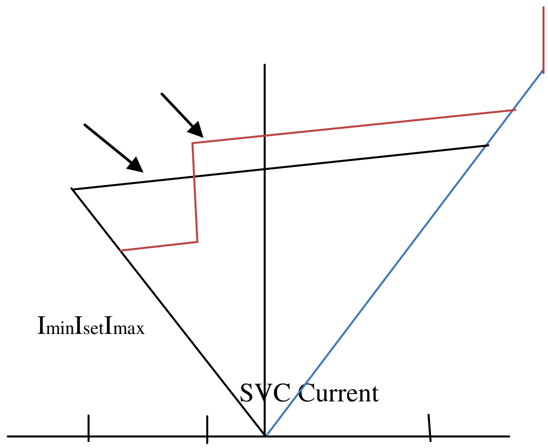
Volume: 04 Issue: 05 | May -2020 ISSN: 2582-3930

Voltage

Steady state characteristic
Dynamic characteristic
Bmin

Bmax



IminIsetImax

Fig.3 steady-state and dynamic voltage/current Characteristics of the SVC

SVC firing angle model is implemented in this paper. Thus, the model can be developed with respect to a sinusoidal voltage, differential and algebraic equations can be writtenas

$I_{SVC} = -jB_{SVC}V_K$

The fundamental frequency TCR equivalent reactance X_{TCR}

$$X_{TCR} = \frac{\pi X_L}{\sigma - \sin\sigma}$$

Where $\sigma = 2(\pi - \alpha)$, $X_L = \omega L$

And in terms of firing angle $$X_{TCR} = \frac{\pi X_L}{2(\pi-\alpha)+\sin 2\alpha}$$

σ and α are conduction and firing angles respectively

At $\alpha = 90^0$, TCR conducts fully and the equivalent reactance X_{TCR} becomes X_L,while at $\alpha = 180^0$, TCR is blocked and its equivalent reactance becomes infinite.

The SVC effective reactance X_{SVC} is determined by the parallel combination of X_c and X_{TCR}

$$X_{SVC}(\alpha) = \frac{\pi X_C X_L}{Xc[2(\pi-\alpha)+\sin 2\alpha] - \pi XL}$$

Where $X_C = 1/\omega C$

$$Q_k = -V_k^2 \left\{ \frac{X_C[2(\pi-\alpha)+\sin 2\alpha]}{X_L X_C} \right\}$$

The SVC equivalent reactance is given above equation. It is shown in Fig. that the SVC equivalent susceptance ($B_{SVC}=-1/X_{SVC}$)profile, as function of firing angle, does not present discontinuities, i.e., B_{SVC}varies in a continuous, smooth fashion in both operative regions. Hence, linearization of the SVC power flow equations, based on $B_{SVC}$with respect to firing angle, will exhibit a better numerical behavior than the linearized model based on X_{SVC}.

The initialization of the SVC variables based on the initial values of ac variables and the characteristic of the equivalent susceptance (Fig.), thus the impedance is initialized at the resonance point $X_{TCR}=X_C$, i.e. $Q_{SVC}=0$, corresponding to firing angle $\alpha = 115^0$, for chosen parameters of X_L and X_C i.e. $X_L= 0.1134\Omega$ and $X_C = 0.2267\Omega$.

2. *Proposed SVC power flow model:*

The proposed model takes firing angle as the state variable in power flow formulation. From above equation the SVC linearized power flow equation can be written as

$$\begin{bmatrix} \nabla P_k \\ \nabla Q_k \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & \frac{2V_k^2}{\pi X_L}[\cos 2\alpha - 1] \end{bmatrix}^{(i)} \begin{bmatrix} \nabla \theta_k \\ \nabla \alpha \end{bmatrix}^{(i)}$$

At the end of iteration i, the variable firing angle α is updated according to

$$\alpha^i = \alpha^{(i-1)} + \nabla\alpha^i$$

3. SVC CONTROLLER MODEL:

The state equations of the SVC can be written from above figure

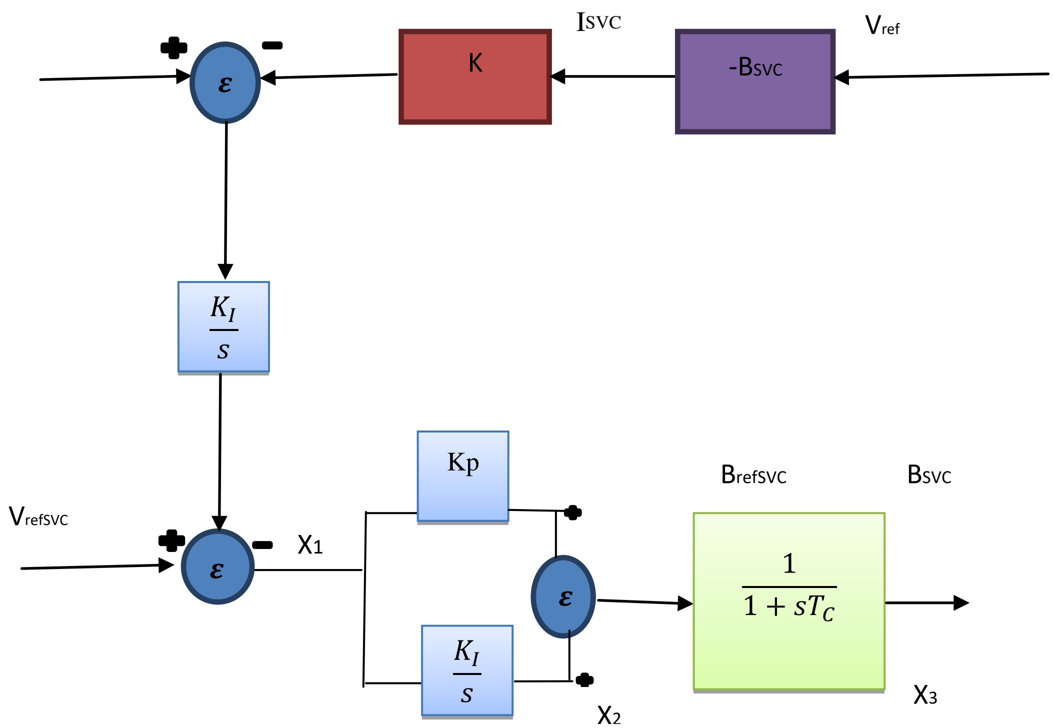


Fig.4 Block diagram of SVC

The state equations of the SVC can be written from above figure

$\dot{X}_{1svc}=\frac{1}{T_m}[V_{SVC}(1+KX_{3SVC})\text{-}X_{1SVC}]$

$\dot{X}_{2svc}= K_I(V_{ref,svc}\text{-}X_{1SVC})$

$\dot{X}_{3svc}=\frac{1}{T_C}[X_{2SVC}+K_P(V_{ref,svc}\text{-}X_{1SVC})\text{-}X_{3SVC}]$

The reactive power Q_{SVC} supplied by the SVC can be written as

$Q_{SVC}=V_{SVC}^2X_{3SVC}$

Linearization of above equations ( )-( ) yields

$\Delta\,\dot{X}_{1svc}=\frac{1}{T_m}[\Delta V_{SVC}(1+KX_{3SVCo})+V_{SVCo}K\Delta X_{3SVC}\text{-}\Delta X_{1SVC}]$

$\Delta\,\dot{X}_{2svc}= K_I(\Delta V_{ref,svc}\text{-}\Delta X_{1SVC})$

$\Delta\,\dot{X}_{3svc}$=$\frac{1}{T_C}$[ΔX_{2SVC}+K_P($\Delta V_{ref,svc}$-ΔX_{1SVC})-ΔX_{3SVC}]
ΔQ_{SVC}= $2V_{SVCo}\Delta V_{SVC}X_{3SVCo}$+$V_{SVCo}^2\Delta X_{3SVC}$
Where "Δ" denotes perturbed value and subscript "o" denotes the nominal value. The above equations are linearized, reordered and then expressed as

$$\begin{bmatrix}\Delta\,\dot{X}_{1svc}\\ \Delta\,\dot{X}_{2svc}\\ \Delta\,\dot{X}_{3svc}\end{bmatrix}=\begin{bmatrix}\frac{-1}{Tm} & 0 & \frac{KV_{SVCo}}{Tm}\\ -K_I & 0 & 0\\ \frac{-K_P}{T_L} & \frac{1}{T_L} & \frac{-1}{T_L}\end{bmatrix}\begin{bmatrix}\nabla X_{1SVC}\\ \nabla X_{2SVC}\\ \nabla X_{3SVC}\end{bmatrix}+\begin{bmatrix}\frac{1}{T_m}(1+KX_{3SVC0})\\ 0\\ 0\end{bmatrix}[\nabla V_{SVC}]$$

Above equation can be written as
$\nabla\,\dot{X}_{svc} = A_{AVC}\nabla X_{SVC}$+$B_{SVC}\nabla V_{SVC}$
Where

$$A_{svc}=\begin{bmatrix}\frac{-1}{Tm} & 0 & \frac{KV_{SVCo}}{Tm}\\ -K_I & 0 & 0\\ \frac{-K_P}{T_c} & \frac{1}{T_c} & \frac{-1}{T_c}\end{bmatrix}$$

And

$$B_{svc}=\begin{bmatrix}\frac{1}{T_m}(1+KX_{3SVC0})\\ 0\\ 0\end{bmatrix}$$

4. INCORPORATION OF SVC IN MULTI-MACHINE POWER SYSTEMS:

In its simplest form SVC is composed of FC-TCR configuration as shown in Fig.2. The SVC is connected to a coupling transformer that is connected directly to the ac bus whose voltage is to be regulated. The effective reactance of the FC-TCR is varied by firing angle control of the thyristors. The firing angle can be controlled through a PI controller in such a way that the voltage of the bus where the SVC is connected is maintained at the desired reference value.

The SVC can be connected at either the existing load bus or at a new bus that is created between two buses. As DAE model is based on power-balance, rewriting of the power-balance equations at the buses with SVC connected in the system requires modification of D2new. When SVC is connected at specified load buses, and gets modified as given below

P_{SVCi}+$P_{Li}(V_i)$-$\sum_{k=1}^{n} V_i\,V_kY_{ik}\cos(\Theta_i$-$\Theta_k$-$\alpha_{ik}) = 0$
i=m+1,……………….,n

$Q_{SVCi} + Q_{Li}(V_i)$ - $\sum_{k=1}^{n} V_i\,V_kV_{ik}\sin(\Theta_i - \Theta_k$ - $\alpha_{ik}) = 0$

i=m+1,………………,n

Obtained state equation after linearization of above equations
$C_{SVC}\nabla V_1 + D_{SVC}\nabla X_{SVC}$+$D_1\nabla V_g$+$D_2\nabla V_1$=0

Or

$D_{SVC}\nabla X_{svc}$+$D_1\nabla V_g$+$D_{2svc}\nabla V_1$=0

Where

D_{2svc}=$C_{svc} + D_2$

The incorporation of the SVC into DAE model of the multi-machine power systemis done on the same line as explained in [2] given as follows:

$$\begin{bmatrix} \nabla\dot{X} \\ \dot{X}_{svc} \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} A_{1mod} & P_{1SVC} & P_{2new} & A_{3new} \\ P_{2SVC} & A_{SVC} & P_{3SVC} & B_{SVC\_new} \\ K_2 & P_{4svc} & K_{1new} & C_{4new} \\ G_2 & D_{SVC} & D_{1new\_svc} & D_{2new\_SVC} \end{bmatrix} \begin{bmatrix} \nabla X \\ \nabla X_{SVC} \\ \nabla z \\ \nabla v \end{bmatrix} + \begin{bmatrix} E \\ 0 \\ 0 \\ 0 \end{bmatrix} \nabla U$$

The state equation for the SVC is given as follow:

$$\nabla^{\cdot} X_{sys\_svc} = A_{sys\_svc} \nabla X_{sys\_svc} + E_{svc} \nabla U$$

The system matrix with SVC is given as

$$A_{SYS\_SVC} = A_{sv2} * (inv(A_{SVY}) * A_{SV3})$$

Where

$$A_{SV1} = \begin{bmatrix} A_{1mod} & P_{1SVC} \\ P_{2SVC} & A_{SVC} \end{bmatrix}$$

$$A_{SV2} = \begin{bmatrix} A_{2new} & A_{3new} \\ P_{3svc} & B_{svcnew} \end{bmatrix}$$

$$A_{SV3} = \begin{bmatrix} K_2 & P_{4svc} \\ G_1 & D_{SVC} \end{bmatrix}$$

$$A_{SV4} = \begin{bmatrix} K_{1new} & C_{4new} \\ D_{1new\_svc} & D_{2new\_svc} \end{bmatrix}$$

III. SUMMARY OF PAPER

A. Conventional method for optimal placement and properly coordinated control of FACTS controllers

Table 2: % Distribution of Conventional method for optimal placement and properly coordinated control of FACTS controllers

S.No.	Conventional method	No. of literatures	% of literatures
1	Phasor measurement	1	1.07
2	Installation	6	6.45
3	Application of projective controls	1	1.07
4	Technique for co-ordination	1	1.07
5	Steady-state model	1	1.07
6	Damp inter-area oscillation	1	1.07

7	SVC placement	1	1.07
8	Steady-state injection model	1	1.07
9	Robust control theory	2	2.15
10	LMP based	2	2.15
11	Application FACTS controllers	1	1.07
12	Sensitivity index	4	4.30
13	Real power performance	1	1.07
14	Multiple time periods	1	1.07
15	Semiconductor technology development	1	1.07
16	Co-ordinate stabilizer	2	2.15
17	Modified model of power flow	1	1.07
18	Line index	1	1.07
19	Controllability index	1	1.07
20	Distributed generation	1	1.07
21	Residue factor	4	4.30
22	Coordinated control	2	2.15
23	FACTS controllers	6	6.45
24	Closed-loop characteristic polynomial	1	1.07
25	Newton-Raphson	3	3.2
26	Variable-structure control theory	1	1.07
27	Singular value decomposition based controller	1	1.07
28	Location for UPFC	2	2.15
29	Voltage control	2	2.15
30	Power system stabilizer	2	2.15
31	Migration of power quality	2	2.15
32	FACTS damping controller	1	1.07
33	Power injection model	2	2.15
34	Excitation control	1	1.07
35	Injection management	2	2.15
36	Electromechanical oscillation	1	1.07
37	Decentralized control theory	1	1.07
38	Cascade multilevel configuration	1	1.07
39	Small-signal stability analysis	1	1.07
40	Phillips-Heffron	1	1.07

	model		
41	Modal speeds	1	1.07
42	Power convertor module	1	1.07
43	Allocation & transmission pricing	1	1.07
44	Mid-point location	1	1.07
45	Continuation power flow	4	4.30
46	Control of phase angle	1	1.07
47	Algebraic modeling	1	1.07
48	Averaging technique	1	1.07
49	Goal attachment method	1	1.07
50	Unified power flow	1	1.07
51	Energy function method	1	1.07
52	Transmission system	1	1.07
53	Planning & protection	1	1.07
54	Var compensation	1	1.07
55	Reactive power management	1	1.07
56	System loadability	1	1.07
57	Investment recovery of FACTS devices	1	1.07
58	Techno economical contribution of FACTS	1	1.07
59	Probabilistic technique	1	1.07
60	Shunt dynamic Var source	1	1.07
61	Practical installation & benefits	1	1.07
62	Heuristic method	1	1.07

Figure

B. Optimization method for optimal placement and properly coordinated control of FACTS controllers

Table 3: % Distribution of optimization methodsreviewed for optimal placement and properly coordinated control of FACTS controllers

S.No.	Optimization method	No. of literatures	% of literatures
1	Optimal power flow	2	28.57
2	Optimization method	3	42.85
3	Optimal control	1	14.28
4	Optimization algorithm	1	14.28

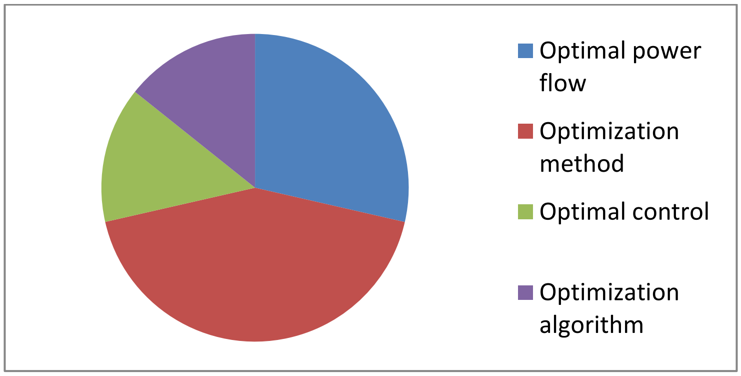


Figure 6: % Pie chart distribution of optimization methods reviewed for optimal placement and properly coordinated control of FACTS controllers

C. Artificial intelligence computational (AIC) technique for optimal location and coordinated control of FACTS controllers in power systems.

Table 4: % Distribution for Artificial intelligence computational (AIC) technique for optimal location and coordinated control of FACTS controllers in power systems

S.No.	AIC technique	No. of literatures	% of literatures
1	Genetic algorithm (G.A.)	22	34.37
2	Artificial intelligence	1	1.56
3	Digital simulation	1	1.56
4	Particle swarm optimization	7	10.93
5	Evolution strategy	5	7.81
6	Bacteria Foraging Optimization Algorithm (BFOA)	2	3.12
7	Fuzzy logic theory	3	4.68
8	Bifurcation theory	1	1.56
9	H infinity norm	1	1.56
10	Bees algorithm	2	3.12
11	Micro genetic algorithm (μG.A.)	1	1.56
12	Simulation by MATLAB	4	6.25
13	Linear programming	1	1.56
14	Simulation	1	1.56

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15	Transient stability simulation	1	1.56
16	Non-linear design technique	3	4.68
17	H∞-optimization technique	3	4.68
18	Novel chain	1	1.56
19	Decision trees	1	1.56
20	Differential algorithm	1	1.56
21	Benders decomposition technique	1	1.56
22	Gravitational search algorithm	1	1.56

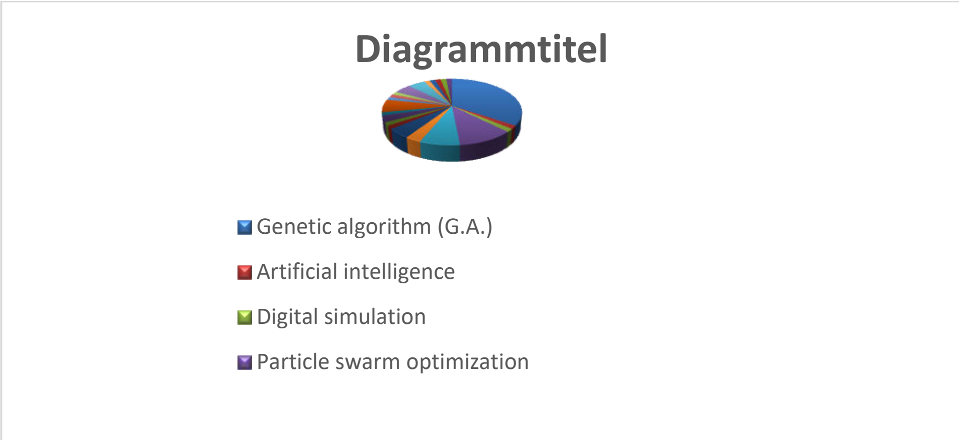

Figure 7: % Pi chart for Artificial intelligence computational (AIC) technique for optimal location and coordinated control of FACTS controllers in power systems

D. Hybrid techniques for optimal placement and properly coordinated control of FACTS controllers

Table 5: % Distribution for hybrid techniques for optimal placement and properly coordinated control of FACTS controllers

S.No.	Hybrid technique	No. of literatures	% of literatures
1	A mixed H_2/H_∞ with regional pole placement	1	11.11
2	DEE+PSO	1	11.11
3	Mixed integer linear disjunctive formulation	1	11.11
4	Hybrid algorithm	1	11.11
5	Feedback linearization technique	1	11.11
6	Hybrid G.A. approach	1	11.11
7	Linear programming (L.P.) based optimal power flow (O.P.F.) algorithm	1	11.11
8	Power flow control & damping of oscillations in power systems	1	11.11
9	Mathematical modelling	1	11.11

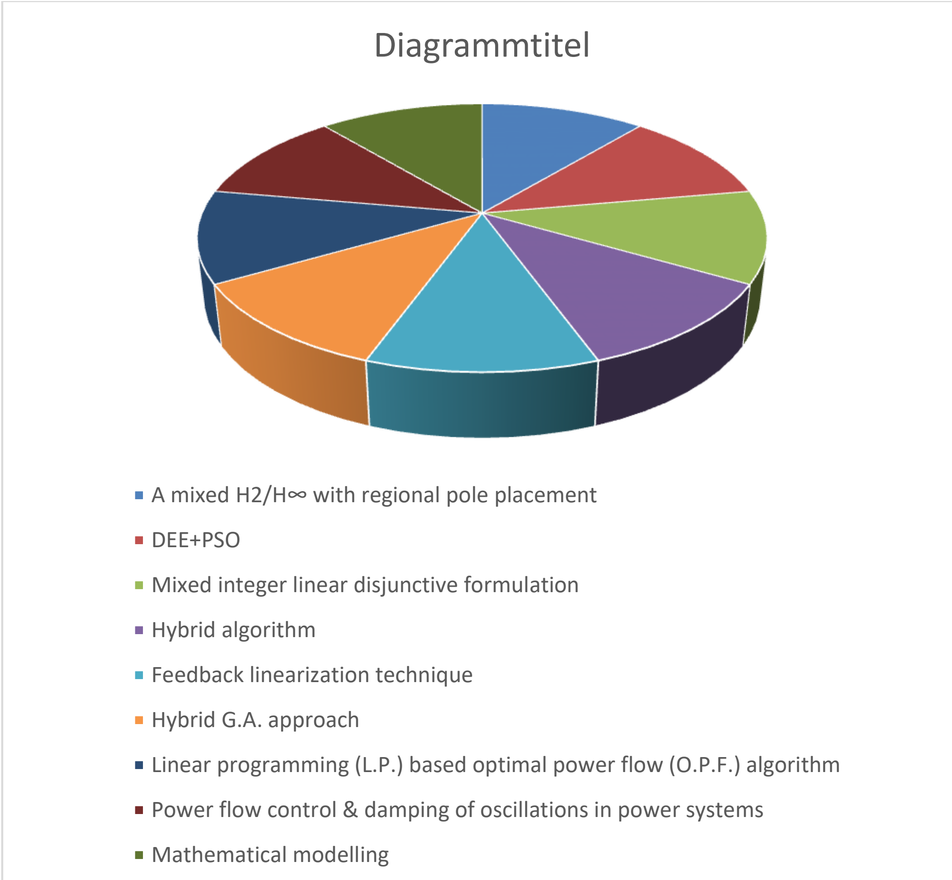

Figure 8: % Pi chart for hybrid techniques for optimal placement and properly coordinated control of FACTS controllers

IVCONCLUSION AND FUTURE SCOPE OF WORK

The following conclusions made from this survey article as follows:

- AI techniques are more suitable as compared to conventional and optimization techniques for optimal DG planning in distribution power system networks from different power system performance point of view.
- Hybrid AI techniques are also more suitable as compared to conventional and optimization techniques for optimal DG planning in distribution power system networks from different power system performance point of view.

The following recommendation for future scope of research work as follows:

- Comparison of different types of DG planning with static as well as realistic load modals by AI techniques.
- Comparison of different types of DG planning with static as well as realistic load modals by hybrid AI techniques.
- Comparison of different types of DG and FACTS controller planning with static as well as realistic load modals by AI techniques.
- Comparison of different types of DG and FACTS controller planning with static as well as realistic load modals by hybrid AI techniques

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Akash Gupta isa gradute student of B. Tech, Electrical Engineering from Kamla Nehru Institute of Technology,Sultanpur, U.P., India.