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Article

A comprehensive survey on enhancement of system performances by using different types of FACTS controllers in power systems with static and realistic load models

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Review article

A comprehensive survey on enhancement of system performances by using different types of FACTS controllers in power systems with static and realistic load models



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ABSTRACT

In present time the power demand increases more rapidly in the power generation and transmission and distribution system sectors. For maintaining the power system stability and steady state operation of power systems causes from disturbance, faults and suddenly changing of the load, voltage instability, voltage swell, voltage sag, harmonics, and change in frequency, stability is the most important factor for the power systems. Due to instability, different problems occur in power systems such as fluctuation in voltage and frequency, which may cause damage or failure of power systems.

This article presents taxonomical survey on optimization techniques for enhancement system performance by FACTS controllers such as Thyristor Controlled Series Capacitor (TCSC), Thyristor Controlled Phase Angle Regulator (TC-PAR), Static VAR Compensator (SVC), Dynamic Voltage Restorer (DVR), Sub-Synchronous Series Compensator (SSSC), Static Synchronous Compensator (STATCOM), distributed-STATCOM, Unified Power Flow Controller (UPFC), Generalized Unified Power Flow Controller (GUPFC), Unified Power Quality Conditioners (UPQC), Unified Dynamic Quality Conditioners (UDQC), Interlink Power Flow Controller (IPFC), Generalized Interlink Power Flow Controller (GIPFC) and Hybrid Power Flow Controller (HPFC) etc. in power systems with static and realistic load models. The system performances such as real and reactive power losses, power quality, voltage profile, power system oscillations, loadability of system, reliability and security of system, power system stability, bandwidth of operations, flexible operations, available power transfer capacity, system power factor, environmental etc. are enhanced by optimally placed different types of FACTS controllers in power systems with static and realistic load models. In this survey article will be very much helpful to the researchers and practitioners for finding out the relevant references in the field of enhancement system performances by different types of FACTS controllers in power systems with static and realistic load models.

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Contents

1. Introduction.....	56
2. A taxonomical survey on enhancement of system performances by different types of FACTS controllers in power systems with static and realistic load models.....	57
2.1. Conventional methods.....	57
2.2. Optimization techniques.....	58
2.3. Artificial intelligence computational techniques.....	58
2.4. Hybrid techniques.....	63
3. Summary of paper.....	69
3.1. Conventional techniques.....	69
3.2. Optimization techniques.....	70
3.3. Artificial intelligence computational techniques.....	70
3.4. Hybrid techniques.....	70
3.5. Current techniques.....	71

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3.6. Comparisons of all optimization techniques	71
4. Conclusions and future scopes of the survey article	73
4.1. Conclusions	73
4.2. Future scopes of survey article	73
References	73

Abbreviations

FACTS	Flexible Alternating Current Transmission Systems
ANN	Artificial neural network
ABC	Ant Bee colony algorithm
GA	Genetic algorithm
ABC	Ant bees colony
TCSC	Thyristed controlled series capacitor
TCPAR	Thyristed controlled phase angle regulator
TS	Tabu search
EP	Evolutionary Programming
MMPs	Multi-machine power systems
PSO	Particle swarm optimization
MINLP	Mixed integer non linear programming
MILP	Mixed integer linear programming
SSSC	Static synchronous series capacitor
STATCOM	Static synchronous compensator
TCSC	Thyristed controlled series capacitor
UPFC	Unified power flow controllers
SVC	Static var compensators
SSSC	Sub-series synchronous compensators
SA	Sensitivity Analysis
STATCOM	Static synchronous compensator
DSTATCOM	Distributed-Static synchronous compensator
HPFC	Hybrid power flow controllers

Symbols

f	Supply frequency (50 Hz)
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- Size, location and coordination of FACTS controllers
- Size, location, type and coordination of FACTS controllers

The following conventional techniques are reviewed for the optimization techniques for voltage stability analysis by using different types of FACTS controllers in power systems with static and realistic load models such as Model analysis (Vasquez Arnez and Cevra, 2008; Nam et al., 2000; Perkin and Ira, 1997; Li et al., 2017; Hridya et al., 2015a; Jiang et al., 2010; Guo et al., 2018a; Kinjo et al., 2006; Alhasawi and Jovica, 2012; Pilotto et al., 1997a; Gibbard and Vowles, 2000; Rouco, 1997; Gholipour, 2005; Mehrouachi et al., 2019; Gao et al., 1992; Huang et al., 2000), Index method (Carpinelli et al., 2015; Chang et al., 2009b; M. M. Farsaang, 2004; Okamoto and Kurita, 1995; Bazanella and Shilva, 2001; Pilotto et al., 1997b; Kalyan Kumar et al., 2007; Limyingcharoen et al., 1998; Hammad and Al Sadek, 1989; Canizare et al., 1996; Gubina and Strmcnik, 1995; Lof et al., 1993; Naoto et al., 2003), Controlling method (Ye et al., 2005; Zhu et al., 2010; Wei et al., 2005; Bedoya et al., 2008; Gabrijel et al., 2002; Padhiyaar et al., 1998), Residue analysis (Chen et al., 2003; Krishnan et al., 2018; Adnan et al., 2018), Numerical optimization (Monod and Mohan, 2010; Li and Li, 1993), Eigen value (Li et al., 2012a; Pilotto et al., 1997c; Wang et al., 2003; Hossain et al., 2012) and Sensitivity method (Leiu et al., 2000; Hridya et al., 2015b; Zhao and Jiang, 1995; Ooi et al., 1997; Crisan, 1994; Cutsem, 1995; Subhanga et al., 2002; Mehraeen et al., 2010; Fang et al., 2009; Pal, 2002; Morioka et al., 1999b; Manganuril et al., 2016; Wei et al., 2004; Ciofi et al., 2002; Bakar and Desa, 2017; Hamed et al., 2013; Tiwari and Ajjarapu, 2011; Ardhakhani et al., 2016).

The following optimization techniques are reviewed for the optimization techniques for voltage stability analysis by using different FACTS controllers in power systems with static and realistic load models such as Linear programming (Ara et al., 2012; Chen et al., 1995; Wang and Tan, 2002; Zhang et al., 2004; Panda and Ramnarayan, 2006; Morioka et al., 1999a), MINLP (Cai et al., 2005; Saba et al., 2010; Nojavan et al., 2018; Tan and Wang, 1997; Zarghami et al., 2010; Nikoobakht et al., 2018), Stochastic Load Flow (Wibowo et al., 2011; Rahimzadeh and Bina, 2011; Jadidbonab et al., 2019; Noruzian et al., 1997; Hamon et al., 2013), Adaptive control law (Tan, 1996; Muzzammel et al., 2015), Analytical Approach (Araby et al., 2002; Orfano Gianni and Bacher, 2003; Verma and Srivastava, 2005; Huang et al., 2012; Orfanogianni and Bacher, 2003; Wen et al., 2004; Tan and Wang, 1998; Gitizadeh, 2009; Sode Yome et al., 2006; Limyingcaron et al., 1998; Gao et al., 2017), Dynamic Programming (Khalesi et al., 2011; Kumkhratuge et al., 2003), OPF (Gan et al., 2000; Kamarposhti et al., 2008; Acchha et al., 2000; Padhy and Abdel, 2004; Zhang et al., 2001; Lie and Deng, 1997a; Xhiao et al., 2002; Choudari et al., 2004; Perez et al., 2006; Kamel et al., 2015; Carpinelli et al., 2006; Ajjharapu and Crishty, 1992; Hu et al., 2016; Goliphour and Shadate, 2005; Noruzhian et al., 1997; Vahhedhi et al., 1999) and Mixed-Integer Optimization (Gharbex et al., 2001; Zharghami et al., 2010; Ghaliana et al., 1996; Sinh et al., 2006; W. Zang and Tholbherth, 2007; Lie and Deng, 1997b; Araby et al., 2002; Urdhanata et al., 1991; Zou et al., 1999; Kumar and Dhava, 1995; Tahbhoub et al., 2018; Zhou, 1993; Ajjarapu and Chrithy, 1992; Ghyugi et al., 1999; Marthins and Lheema, 1990; Lhu and Abhour, 2002; Yorinho et al., 2003; Chang and Huang, 1997a; Lashkar et al., 2012; Parker et al., 1996; Araby et al., 2002;

1. Introduction

The different types of FACTS controllers are used for enhancement of system performances. These are discussed as follows:

- Series connected FACTS controllers:* Such as TCSC, SSSC, TCR, TCR and TCR etc.
- Shunt connected FACTS controllers:* Such as SVC, DVR, STATCOM and DSTATCOM etc.
- Series-series connected FACTS controllers:* Such as IPFC and GIPFC etc.
- Shunt-series connected FACTS controllers:* Such as UPFC, GUPFC and HPFC etc.

The above types of FACTS controllers are more effective for enhancement of system performances viewpoints.

The system performances enhanced by FACTS Controllers in power systems with static and realistic load models. These different issues are considered by researchers are as follows:

- Size and location of FACTS controllers
- Size, location and type of FACTS controllers
- Location and type of FACTS controllers
- Size and type of FACTS controllers
- Size, type and coordination of FACTS controllers

Table 1
Different types of FACTS controllers and their controlled parameters.

Types of FACTS	Characteristics	Controlled parameters	Examples
Series	Control reactance	Real & reactive power	TCSC, SSSC & TC-PAR etc.
Shunt	Control susceptance	Reactive power	SVC, STATCOM & DSTATCOM etc.
Series–Series	Control V and δ	Real & reactive power	IPFC & GIPFC etc.
Shunt-Series	Control X, V and δ	Real & reactive power	UPFC, UPQC, UDQC, GUPFC & HPFC etc.

Xie et al., 2003; Abdel-Magid et al., 2000; Mihilhac et al., 1996; Ghyugyi et al., 1999; Wildenhues et al., 2014; Paramasivam et al., 2013; Deng et al., 2018; Qader, 2015; Orfano Gianni and Bacher, 2003; Kumar et al., 2007a).

The following artificial intelligence techniques are reviewed for the optimization techniques for voltage stability analysis by using different types of FACTS controllers in power systems with static and realistic load models such as GA (Dhas et al., 2000; Hazhra et al., 2007; Yashida et al., 2000b; Vijaykumar and Kumudini Devi, 2007; Chandrasekaran et al., 2005–2009; Yang et al., 2007; Accha et al., 2004; Morris et al., 2003; Bakhirtzis et al., 2002; Vijayakumar and Kumudini Devi, 2008; Priti et al., 2011; Tukharam et al., 1996; Gerbhex et al., 2001; Vijaya kumar and Kumudini devi, 2007; Abdel-Magid et al., 1999), Symbiotic organism search (SOS) algorithm (Pandey and Gupta, 2018; Verbic and Gubina, 2004; Dillon, 1991; Pandha and Ardhill, 2007), Computational simulations (Lima et al., 2003; Vijaykumar and Kumudini Devi, 0000; Sadhegh et al., 2005; Renzh et al., 1999), Tabu search based method (Mori and Goto, 2000), Monte Carlo simulation (Etingov et al., 2007; Blanco et al., 2011), Intelligent programming (Shadhegh et al., 2005; Chang and Huang, 1997b), ABC algorithm (Mohamad Idris et al., 2010; Shyh and Xian, 2013), ANN method (Feurthe Eshquivel and Accha, 1997; Kheib et al., 1995; Mozghan, 2012; Zeynelgil and Demiroren, 2002; Nguyen et al., 2008; Daskh and Paanda, 2000; Nar et al., 1990), Fuzzy linear programming (Tomsovics, 1992; Cai and Erlich, 2006; Venkatesh et al., 1999; Mishra et al., 2000; Daas et al., 2000; Limchron et al., 1998), and PSO method (Benabidh et al., 2009; Panda and Ardil, 2008; Rashidi and Hawary, 2009; Abido, 2002; Yoshida et al., 2000; Kannan et al., 2004; Yashida et al., 2000a; Shayeghi et al., 2009) (see Table 1).

The hybrid techniques are reviewed for the optimization techniques for voltage stability analysis by using different types of FACTS controllers in power systems with static and realistic load models such as hybrid of ABC and ANN (Satheesh and Manigandan, 2013), hybrid of GA and OPF (Chung and Li, 2001; Phalliate et al., 1997; Mustafa and Chiew, 2008; Subhanga and Kulkaarni, 2002; Gerbex et al., 2001; Xu and Ahmad Zaid, 1995; Liu et al., 2006; Abhou Elaa et al., 2010; Mithulantan et al., 2003; Mahdad et al., 2009; Ippolito et al., 2006), hybrid of OPF and SA (Chatterji et al., 2007; So et al., 2005), hybrid of GA and FZ (Jeevarathinam, 2006; Li et al., 2012b), hybrid of SA and EP (Alamhelu et al., 2008), hybrid of PSO And MINLP (Ko et al., 2009), hybrid of SA and MILP (Chung et al., 2003), hybrid of OPF and PSO (Chandra sekaran et al., 2009; Niknam et al., 2012), hybrid of ABC and OPF (Rezaei and Karami, 2013), hybrid of Lyapunov Theory and Fuzzy Logic (Kimkhratug, 2012) and hybrid of OPF and Fuzzy Logic (Nurzian et al., 1996).

Some other techniques are reviewed for the optimization techniques for voltage stability analysis by using different types of FACTS controllers in power systems with static and realistic load models such as Energy approach (Hoque, 2004, 2008; Wenzel

and Leibfried, 2012; Goksu et al., 2014; Pillottho et al., 1997; Yeu et al., 2001; Kundur and Morison, 1997; Zhou, 1993; Kobayashi et al., 2003; Milhalic and Zhunko, 1996; Farsangi et al., 2007; Niaki and Irhavani, 1996; Manshour et al., 1994; Khederzadeh and Ghorbani, 2012a; Aghaei et al., 2016; Angqhuist et al., 1993; Azhbe et al., 2005), Active control technique (Khederzadeh and Ghorbani, 2012b; Gonzhalez et al., 2010; Shong et al., 2010; Baek et al., 2013; Guo et al., 2018b; Kanan et al., 2004; Edris, 2000; Whang and Shwift, 1996; Paphic et al., 1997; Kumar et al., 2007b; Reis and Maciel Barbosa, 2006; Mohsen et al., 2013; Zenghyu et al., 2000; Venkataramanan and Johnson, 2002; Mancilla David and Venkataramanan, 2000; Khederzadeh and Sidhu, 2006; Pilotto et al., 1997; Canizares et al., 1999; Park and Baek, 2012; Noruzian et al., 1999; Shukla and Mili, 2017), Passivity method (Yorinno et al., 2003; Gui et al., 2016; Zheao et al., 1998; Sauer and Pai, 1990; Conejo et al., 2006; Chang et al., 2009a; Rhao et al., 2000; Kundhur et al., 2004; Potamianakis and Vournas, 2006), Hybrid technique (Kejani and Gholipour, 2017; Hu et al., 2018; Dhong et al., 0000; Hajagos and Danai, 1998; Kumkrahug et al., 2003; Vahidna et al., 2016; Hua et al., 2019), Pole placement techniques (Faaershanghi et al., 2007; Kesshel and Ghlavitsch, 1986; Thukaram et al., 2005; Ahsae and Sadeh, 2011), Graph search algorithm (Madhtharad et al., 2005; Niaki and Irhvani, 1996; Larshen et al., 1995), Decomposition coordination methods (DCM) (Olivheira, 1994; Whei et al., 2005), Whale optimization algorithm (Sahu et al., 2017), Gray Wolf Optimizer (Ladhumaor et al., 2017a), Meta-heuristic algorithm (Ladhumaor et al., 2017b; Wildheunhues et al., 2015), Salp Swarm Optimizer (Kuyu and Vatansever), Grasshopper Optimization Algorithm (Hamour et al.) and Ant Lion Optimization Technique (George et al.), Spider Monkey Optimization (Nayak et al.; Hazrati et al.; Kaur et al.; Behera et al., 2018).

The enhancement of system performances by different types of FACTS controllers in power systems with static and realistic load models are presented in Tables 2–6.

This article organized as follows: Section 2 discusses the survey on optimization techniques for system performances by different types of FACTS controllers. Section 3 introduces the summary of the article. Section 4 discusses the conclusions and future scope of survey article.

2. A taxonomical survey on enhancement of system performances by different types of FACTS controllers in power systems with static and realistic load models

A taxonomical survey on optimization techniques for enhancement of system performances by different types of FACTS controllers in power systems with static and realistic load models. The taxonomical survey of these optimization techniques such as conventional techniques, optimization techniques, artificial computational intelligence, hybrid and current optimization techniques are presented in Tables 2–6, respectively.

The conventional techniques, optimization techniques, artificial computational techniques, hybrid techniques and current techniques are discussed in Sections 2.1–2.5, subsequently.

2.1. Conventional methods

The conventional methods for enhancement of system performances by different types of FACTS controllers in power systems with static and realistic load models are discussed as follows:

Model analysis method: Modal analysis is used for the dynamic properties of systems in the frequency domain. These are the collection of (1) sensors (transducers) like accelerometers, load cells, or stereo photogrammetric cameras (2) data acquisition

system and an A/D converter front end for digitize analog instrumentation signals and (3) host Personal computer to view the data and analyze it. Modal analysis method uses the overall mass and stiffness of a structure to find out the various time periods at which it will naturally resonate.

Index method: This method is a composite, statistic a measure of changes in a group of individual data points or a compound measures that aggregate multiple indicators. Indexes summarize and rank specific observations. Indexes are usually weighted equally, unless there are some reasons against it (i.e. if two items reflect each other essentially in same aspect of a variable, they could have a weight of 0.5 each).

Controlling method: The objective of this method is to develop a control model for controlling such systems in an optimum manner without delay or overshoot and ensuring control stability. This type of controller monitors the controlled process variable and compares it with the reference or set point. The error signal is the difference between actual and desired value of the process variable. Therefore major application of controlling method is in control systems, which deals with the design of process control systems for industry, other applications range far beyond this.

Residue analysis method: Residues method can be computed very easily and once known, allow the determination of general contour integrals via the residue theorem. The residue theorem is used in the integral is extended to the complex plane and its residues are computed, and real axis is extended to a closed curve enclosed by a half circle in the upper or lower half plane and forming a semicircle. Therefore the half part of the integral will tend towards zero as the radius of the half-circle increases, leaving only the real-axis part of the integral.

Numerical optimization method: In this method algorithms that use numerical approximation for the problems of mathematical analysis. These methods are finds application in all fields of engineering and the physical sciences, but in 21st century also the life sciences, social sciences, medicine, business. Maths and computer that generates, analyzes and implements algorithms the growth in power and the revolution in computing has raised the use of realistic mathematical models. This method continues this long tradition of practical mathematical calculations.

Eigen value method: Eigen value algorithms may also find eigenvectors. Algorithms produce every eigen value; others will produce a few, or only one. Algorithms can also be used to find all Eigen values. When an Eigen value of a matrix has been chosen, it can be used to either direct the algorithm towards a different solution next time. When an Eigen value does not produce eigenvectors, then use an inverse iteration based algorithm with μ set to a close approximation to the Eigen value.

Sensitivity based method: Sensitivity analysis is useful for following purposes:

- Testing the robustness of a model or system.
- Increased the relationships between input and output variables in a system or model.
- Searching for errors in the model.
- Model simplification.

2.2. Optimization techniques

The optimization techniques for enhancement of system performances by different types of FACTS controllers in power systems with static and realistic load models are discussed as follows:

Linear programming method: Linear programming is a method to achieve the best outcome in a mathematical model which is represented by linear relationships. Linear programming is a

technique used for the optimization of a linear objective function, subject to linear equality and linear inequality constraints. Its objective is a real valued function. A linear programming algorithm finds a point where this function has the smallest (or largest) value if such a point exists.

Mixed integer non linear programming (MINLP): Mixed integer nonlinear programming is used to solve optimization problems with continuous and discrete variables. MINLPs arise in applications in a wide range of fields including chemical engineering, finance and manufacturing.

Stochastic load flow method: Stochastic is an adjective word in English that describes something was randomly determined. The word to describe a mathematical object called a stochastic process, but now in mathematics the terms stochastic process and random process are considered interchangeable.

Adaptive control law method: Adaptive control is a method used to controlled system with parameters which vary or are initially uncertain. E.g. as an aircraft flies, its mass will slowly decreases as a result of fuel consumption, a control law is needed that adapts itself to such changing conditions. This method is different from robust control method that it does not requires prior information about the bounds on these time varying parameters, robust control changes are within given value the control method need not to be changed, while adaptive control method is concerned with control law changing itself.

Analytical approach: Analytical approach is used for analysis to break a known problem into the sub parts necessary to solve it. When the approach is ready to solve a problem, then it determines the probability of solving it. Analytical approach is used only for approach that works on difficult problems. Analytical approach is also called as “structuring one’s analysis”. In this analysis a problem is break down into different smaller problems, by which they can be solved individually. Therefore a good analysis uses a process to direct the analysis.

Dynamic programming: This programming method is used for solving a problem by breaking it into different simpler sub problems, after solving these sub problems and stored their results using a memory-based data structure. These sub problem results is indexed in some way, typically based on the values of its input parameters, so as to facilitate its lookup. So same sub problem occurs at next time, in place of recomputing its solution, one simply looks up the previously computed solution, thereby saving computation time. This technique of storing solutions to sub problems instead of recomputing them is called memorization.

Optimum power flow (OPF) method: Power flow method is important for planning future expansion of power systems as well as in determining the best operation of existing systems. The main information collected from the power flow study is the magnitude and phase angle of the voltage at each bus and the real and reactive power flowing in each line. There are some programs which used the linear programming to find out the optimal power flow and the conditions which give the lowest cost per kilowatt hour delivered.

Mixed-integer optimization method: An integer problem in optimization method is a mathematical solution, where some or all of the variables are limited to be integers. The term refers to integer linear programming, in which the objective function and the constraints are linear. If some decision variables are not discrete, then the problem is known as mixed-integer programming problem.

2.3. Artificial intelligence computational techniques

The artificial intelligence computational techniques for enhancement of system performances by different types of FACTS controllers in power systems with static and realistic load models are discussed as follows:

Table 2

A survey on conventional methods for enhancement of system performances by different types of FACTS controllers in power systems with static and realistic load models.

Ref. No.	Author	Year	Power system performance	FACTS controllers used	Parameters for optimization	Load models	Techniques	Future work
Vasquez Arnez and Cevra (2008)	R. Leon Vasquez et al.	2008	System stability	SVC	Location & size	Static	Model analysis	Multi-objective task
Nam et al. (2000)	Hae-Kon Nam et al.	2000	Power loss reduction	TCSC	Location & size	Static	Model analysis	Hybrid techniques
Perkin and Ira (1997)	B. K. Perkins	1997	Power system stability	STATCOM	Location & size	Static	Model analysis	Practical implementation
Li et al. (2017)	Can Li et al.	2017	System protection	DSTATCOM	Location & size	Static	Model analysis	Robustness
Hridya et al. (2015a)	Hridya.K.R et al.	2015	System stability	UPFC	Location & size	Static	Model analysis	Hybrid techniques
Jiang et al. (2010)	Xia Jiang et al.	2010	System stability	SVC & TCSC	Location & size	Static	Model analysis	Realistic load models
Guo et al. (2018a)	Yifei Guo et al.	2018	System reliability	SVC & STATCOM	Location & size	Static & realistic	Model analysis	Environmental friendliness
Kinjo et al. (2006)	T. Kinjo et al.	2006	System stability	SVC & UPFC	Location, size & type	Static	Model analysis	Practical implementation
Alhasawi and Jovica (2012)	F. B. Alhasawi et al.	2012	Improve the reliability of supply	TCPAR	Location, size & type	Static	Model analysis	Environmental friendliness
Pilotto et al. (1997a)	L. A. S. Pilotto et al.	1997	Power quality	SVC & UPQC	Location, size & type	Static	Model analysis	Realistic load models
Gibbard and Vowles (2000)	M. J. Gibbard et al.	2000	System protection	TCSC	Location, size & type	Static	Model analysis	Practical implementation
Rouco (1997)	L. Rouco et al.	1997	Power quality	GUPFC	Location, size & type	Static	Model analysis	Robustness
Gholipour (2005)	E. Gholipour et al.	2005	System protection	IPFC	Location & size	Static	Model analysis	Realistic load models
Mehouachi et al. (2019)	Ines Mehouchi et al.	2019	System reliability	HPFC	Location & size	Static	Model analysis	Robustness
Gao et al. (1992)	B.Gao et al.	1992	Power system stability	GIPFC	Location & size	Static	Model analysis	Robustness
Huang et al. (2000)	Z. Huang et al.	2000	Power quality	SVC	Location, size & type	Static	Model analysis	Practical implementation
Carpinelli et al. (2015)	G. Carpinelli et al.	2015	Power quality	TCSC	Location, size & type	Static	Index method	Realistic load models
Chang et al. (2009b)	B. Chang et al.	2009	Power system reliability	STATCOM	Location, size & type	Static	Index method	Practical implementation
M. M. Farsaang (2004)	M. M. Farsang et al.	2004	Active power loss	DSTATCOM	Location, size & type	Static	Index method	Robustness
Okamoto and Kurita (1995)	H. Okamoto et al.	1995	System reliability	UPFC & UPQC	Location, size & type	Static	Index method	Environmental friendliness
Bazanella and Shilva (2001)	A. S. Bazanella et al.	2001	Harmonic reduction	SVC & TCSC	Location & size	Static	Index method	Hybrid techniques
Pilotto et al. (1997b)	Pilotto L et al.	1997	Power system control	SVC & STATCOM	Location & size	Static	Index method	Practical implementation
Kalyan Kumar et al. (2007)	B. Kalyan Kumar et al.	2007	System protection	SVC & UPFC	Location & size	Static	Index method	Environmental friendliness
Limyingcharoen et al. (1998)	S. Limyingcharoen et al.	1998	Power system stability	TCPAR	Location, size & type	Static	Index method	Hybrid techniques
Hammad and Al Sadek (1989)	A.E. Hammad, et.al	1989	System protection	SVC	Location, size & type	Static	Index method	Realistic load models
Canizares et al. (1996)	C. A. Canizares et al.	1996	Voltage collapse	TCSC	Location, size & type	Static	Index method	Hybrid techniques
Gubina and Strmcnik (1995)	Gubina F et al.	1995	Voltage collapse	GUPFC	Location, size & type	Static	Index method	Realistic load models
Lof et al. (1993)	Lof PA et al.	1993	System stability	IPFC	Location, size & type	Static	Index method	Environmental friendliness
Naoto et al. (2003)	Naoto Y et al.	2003	Voltage collapse	HPFC	Location & size	Static	Index method	Hybrid techniques
Ye et al. (2005)	Yang Ye et al.	2005	System stability	GIPFC	Location & size	Static	Controlling method	Robustness
Zhu et al. (2010)	Jizhong Zhu et al.	2010	Power distribution planning	SVC	Location & size	Static	Controlling method	Realistic load models
Wei et al. (2005)	Xuan Wei et al.	2005	System protection	TCSC & SSSC	Location, size & type	Static	Controlling method	Practical implementation
Bedoya et al. (2008)	D. Bedoya et al.	2008	Power quality	STATCOM	Location, size & type	Static	Controlling method	Realistic load models

(continued on next page)

Table 2 (continued).

Ref. No.	Author	Year	Power system performance	FACTS controllers used	Parameters for optimization	Load models	Techniques	Future work
Gabrijel et al. (2002)	U. Gabrijel et al.	2002	System stability	DSTATCOM	Location, size & type	Static	Controlling method	Practical implementation
Padhiyaar et al. (1998)	K. R. Padiyar et al.	1998	System stability	UPFC	Location, size & type	Static	Controlling method	Environmental friendliness
Chen et al. (2003)	J. Chen et al.	2003	System stability	SVC & TCSC	Location, size & type	Static	Residue analysis	Robustness
Krishnan et al. (2018)	V. V. G. Krishnan et al.	2018	System protection	SVC & STATCOM	Location & size		Residue analysis	Robustness
Adnan et al. (2018)	M. Adnan et al.	2018	Power quality	SVC & UPFC	Location & size	Realistic	Residue analysis	Realistic load models
Monod and Mohan (2010)	S. W. Mohod et al.	2010	Active power loss	TCPAR & DVR	Location & size	Static	Numerical Optimization	Robustness
Li and Li (1993)	B. H. Lee et al.	1993	Power system stability	SVC	Location, size & type	Static	Numerical Optimization	Hybrid techniques
Li et al. (2012a)	Yong L et al.	2012	Power oscillation	TCSC	Location, size & type	Static	Eigen value	Environmental friendliness
Pilotto et al. (1997c)	L.A.S. Pilotto et al.	1997	Harmonic reduction	GUPFC	Location, size & type	Static	Eigen value	Environmental friendliness
Wang et al. (2003)	Hai Feng Wang et al.	2003	System control	IPFC	Location, size & type	Static	Eigen value	Practical implementation
Hossain et al. (2012)	M. J. Hossain et al.	2012	Power quality	HPFC	Location, size & type	Static	Eigen value	Environmental friendliness
Leiu et al. (2000)	G. Li et al.	2000	Power system stability	GIPFC & UPQC	Location & size	Static	Sensitivity method	Realistic load models
Hridya et al. (2015b)	Hridya. K.R. et al.	2015	System stability	SVC & TCSC	Location, size & type	Static	Sensitivity method	Environmental friendliness
Zhao and Jiang (1995)	O. Zhao et al.	1995	Power distribution planning	SVC & STATCOM	Location, size & type	Static	Sensitivity method	Realistic load models
Ooi et al. (1997)	Ooi B et al.	1997	System stability	SVC & UPFC	Location, size & type	Static	Sensitivity method	Robustness
Crisan (1994)	Crisan et al.	1994	Voltage collapse	TCPAR	Location, size & type	Static	Sensitivity method	Hybrid techniques
Cutsem (1995)	T. Van Cutsem et al.	1995	Power quality	SVC & DVR	Location, size & type	Static	Sensitivity method	Environmental friendliness
Subhanga et al. (2002)	K. N. Shubhanga et al.	2002	System stability	TCSC	Location & size	Static	Sensitivity method	Realistic load models
Mehraeen et al. (2010)	Mehraeen S et al.	2010	Power quality	GUPFC	Location & size	Static	Sensitivity method	Hybrid techniques
Fang et al. (2009)	Fang X et al.	2009	Power quality	IPFC	Location & size	Static	Sensitivity method	Realistic load models
Pal (2002)	Pal BC	2002	System stability	HPFC	Location, size & type	Static	Sensitivity method	Robustness
Morioka et al. (1999b)	Y. Morioka et al.	1999	System stability	GIPFC	Location, size & type	Static	Sensitivity method	Environmental friendliness
Manganuril et al. (2016)	Yogasree Manganuril et al.	2016	System stability	SVC & SSSC	Location, size & type	Static	Sensitivity method	Realistic load models
Wei et al. (2004)	Xuan Wei et al.	2004	System stability	TCSC	Location, size & type	Static	Sensitivity method	Environmental friendliness
Ciofi et al. (2002)	Carmine Ciofi et al.	2002	System stability	GUPFC & DVR	Location, size & type	Static	Sensitivity method	Hybrid techniques
Bakar and Desa (2017)	Noorsakinah Abu Bakar et al.	2017	System stability	IPFC & DVR	Location & size	Static	Sensitivity method	Robustness
Hamed et al. (2013)	Hamed HD et al.	2013	Power quality	HPFC	Location & size	Static	Sensitivity method	Realistic load models
Tiwari and Ajjarapu (2011)	S. Greene et al.	1997	Voltage collapse	TCSC & SSSC	Location & size	Static	Sensitivity method	Environmental friendliness
Ardhakhani et al. (2016)	Mostafa Sahraei Ardakani et al.	2016	Power quality	GUPFC & UPQC	Location & size	Static	Sensitivity method	Robustness

General algorithm: Genetic algorithm is the process of selection that belongs to the larger class of evolutionary algorithms. These techniques are basically used to generate solutions for optimization and search problems depending upon bio inspired operators such as crossover and selection. Genetic algorithms are introduced by John Holland in 1960 based on the concept of Darwin's theory of evolution.

Symbiotic organism search (SOS) algorithm: This algorithm simulates the symbolic interaction strategies adopted by organisms to survive and propagate in the ecosystem. Twenty-six unconstrained mathematical problems and four structural engineering

design problems are tested and obtained results compared with other well-known optimization methods. Obtained results confirm the excellent performance of the SOS method in solving various complex numerical problems.

Computational simulations: These methods are used for the behavior of a system using a computer to simulate the output of a mathematical model associated with system. Simulation of a system is given by the running of the system's model. These are realized by the computer programs that can be either small running instantly on small devices or large scale programs that run for hours or days on network based on groups of computers.

Table 3

A survey on optimization techniques for enhancement of system performances by different types of FACTS controllers in power systems with static and realistic load models.

Ref. No.	Author	Year	Power system performance	FACTS controllers used	Parameters for optimization	Load models	Techniques	Future work
Ara et al. (2012)	A. Lashkar Ara et al.	2012	Power loss reduction	TCSC	Location & size	Static	Linear programming	Environmental friendliness
Chen et al. (1995)	X. Chen et al.	1995	System stability	GUPFC	Location & size	Static	Linear programming	Environmental friendliness
Wang and Tan (2002)	Y. Wang et al.	2002	System Improvement	IPFC	Location, size & type	Static	Linear programming	Realistic load models
Zhang et al. (2004)	Zhang X.-P et al.	2004	System reliability	HPFC	Location, size & type	Static	Linear Programming	Environmental friendliness
Panda and Ramnarayan (2006)	Sidhartha Panda et al.	2006	Voltage regulation improvement	GIPFC	Location, size & type	Static	Linear programming	Hybrid techniques
Morioka et al. (1999a)	Y. Morioka et al.	1999	Power loss reduction	SVC & UPQC	Location, size & type	Static	Linear programming	Robustness
Cai et al. (2005)	L.J. Cai et al.	2005	System stability	TCSC	Location, size & type	Static	MINLP	Environmental friendliness
Saba et al. (2010)	K. Sebaa et al.	2010	Power quality	SVC & TCSC	Location & size	Static	MINLP	Robustness
Nojavan et al. (2018)	Morteza Nojavan et al.	2018	Minimization of the total annual energy losses	SVC & STATCOM	Location & size	Static & realistic	MINLP	Realistic load models
Tan and Wang (1997)	Yoke Lin Tan et al.	1997	Power system stability	SVC & UPFC	Location & size	Static	MINLP	Robustness
Zarghami et al. (2010)	Zarghami M et al.	2010	Power system stability	TCPAR	Location & size	Static	MINLP	Realistic load models
Nikoobakht et al. (2018)	Ahmad Nikoobakht et al.	2018	Power system stability	SVC & UPDC	Location & size	Static	MINLP	Realistic load models
Wibowo et al. (2011)	Rony Seto Wibowo et al.	2011	Power System Improvement	TCSC & UPDC	Location & size	Static	Stochastic Load Flow	Practical implementation
Rahimzadeh and Bina (2011)	Sajad Rahimzadeh et al.	2011	System stability	GUPFC	Location, size & type	Static	Stochastic Load Flow	Environmental friendliness
Jadidbonab et al. (2019)	M. Jadidbonab et al.	2019	System protection	IPFC & SSSC	Location, size & type	Static	Stochastic Load Flow	Hybrid techniques
Noruzian et al. (1997)	M. Noroozian et al.	1997	System protection	HPFC	Location, size & type	Static	Stochastic Load Flow	Environmental friendliness
Hamon et al. (2013)	Camille Hamon et al.	2013	Power loss reduction	GIPFC	Location, size & type	Static	Stochastic Load Flow	Practical implementation
Tan (1996)	Y. L. Tan et al.	1996	Power capacity maximization	SVC	Location, size & type	Static	Adaptive control law	Environmental friendliness
Muzzammel et al. (2015)	Raheel Muzzammel et al.	2015	System reliability	TCSC	Location & size	Static	Adaptive control law	Realistic load models
Araby et al. (2002)	E. E. El-Araby et al.	2002	System stability	GUPFC	Location & size	Static	Analytical Approach	Practical implementation
Orfano Gianni and Bacher (2003)	T. Orfano Gianni	2003	Power quality	IPFC	Location & size	Static	Analytical Approach	Realistic load models
Verma and Srivastava (2005)	M. K. Verma et al.	2005	System stability	HPFC	Location & size	Static	Analytical Approach	Practical implementation
Huang et al. (2012)	Jiansheng Huang et al.	2012	System reliability	TCSC	Location & size	Static	Analytical Approach	Practical implementation
Orfanogianni and Bacher (2003)	Tina Orfanogianni et al.	2003	System protection	GUPFC	Location & size	Static	Analytical Approach	Practical implementation
Wen et al. (2004)	Wen et al.	2004	Power system stability	GIPFC	Location, size & type	Static	Analytical Approach	Hybrid techniques
Tan and Wang (1998)	Y.L. Tan et al.	1998	Power system stability	SVC	Location, size & type	Static	Analytical Approach	Practical implementation
Gitizadeh (2009)	M. Gitizadeh et al.	2009	Power quality	TCSC	Location, size & type	Static	Analytical Approach	Environmental friendliness
Sode Yome et al. (2006)	A. Sode-Yome et al.	2006	System stability	GUPFC	Location, size & type	Static	Analytical Approach	Hybrid techniques
Limyingcaron et al. (1998)	S. Limyingcharoen et al.	1998	Power system stability	IPFC	Location, size & type	Static	Analytical Approach	Practical implementation

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Tabu search based method: Tabu search method proposed by Fred W. Glover in 1986 and formalized in 1989. These searches have a potential to solve a problem and check its immediate

neighbors for finding an improved solution. These search methods have a tendency to become stuck in sub optimal regions. Tabu search method increases the performance of local search by

Table 3 (continued).

Ref. No.	Author	Year	Power system performance	FACTS controllers used	Parameters for optimization	Load models	Techniques	Future work
Gao et al. (2017)	Fei Gao et al.	2017	Power system stability	HPFC	Location & size	Static	Analytical Approach	Hybrid techniques
Khalesi et al. (2011)	Khalesi N et al.	2011	Power system reliability	TCSC	Location & size	Static	Dynamic Programming	Realistic load models
Kumkratuge et al. (2003)	P. Kumkratuge et al.	2003	Power quality	GUPFC	Location & size	Static	Dynamic Programming	Practical implementation
Gan et al. (2000)	De. Gan et al.	2000	System stability	GIPFC	Location & size	Static	OPF method	Environmental friendliness
Kamarposhti et al. (2008)	Kamarposhti et al.	2008	System stability	SVC	Location & size	Static	OPF method	Practical implementation
Acchha et al. (2000)	E. Acha et al.	2000	Power System protection	DSTATCOM	Location & size	Static	OPF method	Environmental friendliness
Padhy and Abdel (2004)	Padhy NP et al.	2004	Power system stability	GUPFC	Location, size & type	Static	OPF method	Environmental friendliness
Zhang et al. (2001)	Zhang XP et al.	2001	Power system reliability	IPFC	Location, size & type	Static	OPF method	Hybrid techniques
Lie and Deng (1997a)	T.T. Lie et al.	1997	Power quality	HPFC & UPFC	Location, size & type	Static	OPF method	Hybrid techniques
Xhiao et al. (2002)	Y. Xia et al.	2002	Power quality	TCSC & DVR	Location, size & type	Static	OPF method	Realistic load models
Choudari et al. (2004)	B. Chaudhari et al.	2004	Power quality	GUPFC	Location, size & type	Static	OPF method	Realistic load models
Perez et al. (2006)	Ambriz-Perez et al.	2006	Power quality	GIPFC	Location & size	Static	OPF method	Realistic load models
Kamel et al. (2015)	Kamel et al.	2015	System stability	SVC & SSSC	Location & size	Static	OPF method	Realistic load models
Carpinelli et al. (2006)	Carpinelli et al.	2006	Power system stability	DSTATCOM	Location & size	Static	OPF method	Environmental friendliness
Ajjharapu and Crishty (1992)	V. Ajjharapu et al.	1992	Power quality	GUPFC	Location & size	Static	OPF method	Robustness
Hu et al. (2016)	F. Hu et al.	2016	System stability	IPFC	Location & size	Static	OPF method	Realistic load models
Golipour and Shadate (2005)	E. Gholipour et al.	2005	System stability	HPFC	Location & size	Static	OPF method	Environmental friendliness
Noruzhian et al. (1997)	M. Noroozian et al.	1997	Power quality	TCSC	Location, size & type	Static	OPF method	Realistic load models
Vahhedhi et al. (1999)	E. Vaahedi et al.	1999	System stability	GUPFC	Location, size & type	Static	OPF method	Robustness
Gharbex et al. (2001)	Stephane Gerbex et al.	2001	Power system stability	SVC & SSSC	Location, size & type	Static	Mixed-Integer Optimization	Practical implementation
Zharghami et al. (2010)	Mahyar Zarghami et al.	2010	System stability	DSTATCOM	Location, size & type	Static	Mixed-Integer Optimization	Robustness
Ghaliana et al. (1996)	F.D. Galiana et al.	1996	Power loss reduction	GUPFC	Location, size & type	Static	Mixed-Integer Optimization	Hybrid techniques
Sinh et al. (2006)	J.G. Singh et al.	2006	Power loss reduction	IPFC	Location & size	Static	Mixed-Integer Optimization	Robustness
W. Zang and Tholbherth (2007)	W. Zhang et al.	2007	System protection	HPFC	Location & size	Static	Mixed-Integer Optimization	Environmental friendliness
Lie and Deng (1997b)	Tjing T. Lie et al.	1997	Power quality	TCSC	Location & size	Static	Mixed-Integer Optimization	Environmental friendliness
Araby et al. (2002)	E. E. El-Araby et al.	2002	Power loss reduction	GUPFC	Location & size	Static	Mixed-Integer Optimization	Realistic load models
Urdhanata et al. (1991)	A.J. Urdanata et al.	1991	Power system reliability	TCSC	Location & size	Static	Mixed-Integer Optimization	Robustness
Zou et al. (1999)	X. Zhou et al.	1999	Power system stability	GUPFC	Location & size	Static	Mixed-Integer Optimization	Robustness
Kumar and Dhava (1995)	N. Kumar et al.	1995	power loss reduction	SVC & SSSC	Location, size & type	Static	Mixed-Integer Optimization	Robustness
Tahboub et al. (2018)	Ahmad M. Tahboub et al.	2018	System stability	DSTATCOM	Location, size & type	Static	Mixed-Integer Optimization	Realistic load models
Zhou (1993)	E.Z. Zhou et al.	1993	System stability	GUPFC & STATCOM	Location, size & type	Static	Mixed-Integer Optimization	Practical implementation
Ajjharapu and Chrithy (1992)	V. Ajjharapu et al.	1992	Power system stability	IPFC	Location, size & type	Static	Mixed-Integer Optimization	Hybrid techniques
Ghyugi et al. (1999)	L. Gyugyi et al.	1999	System protection	HPFC	Location, size & type	Static	Mixed-Integer Optimization	Practical implementation

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relaxing its basic rule. Firstly, at each step worsening moves can be accepted if no improving move is available.

Monte carlo simulation method: Monte Carlo is a method used to understand the impact of risk and uncertainty in financial, project management, cost, and other forecasting models. When

there are different ranges of values as a result, you are beginning to understand the risk and uncertainty in the model. Monte Carlo simulation is told you based on how you create the ranges of estimates how likely the resulting outcomes are. Monte Carlo

Table 3 (continued).

Ref. No.	Author	Year	Power system performance	FACTS controllers used	Parameters for optimization	Load models	Techniques	Future work
Marthins and Lheema (1990)	N. Martins Et al.	1990	System stability	TCSC & DSTATCOM	Location & size	Static	Mixed-Integer Optimization	Realistic load models
Lhu and Abhour (2002)	Y. Lu et al.	2002	System security	GUPFC	Location & size	Static	Mixed-Integer Optimization	Hybrid techniques
Yorinho et al. (2003)	N. Yorino et al.	2003	System security	TCSC & DVR	Location & size	Static	Mixed-Integer Optimization	Realistic load models
Chang and Huang (1997a)	Chang CS et al.	1997	System stability	GUPFC	Location & size	Static	Mixed-Integer Optimization	Hybrid techniques
Lashkar et al. (2012)	Lashkar AA et al.	2012	System stability	SVC & SSSC	Location & size	Static	Mixed-Integer Optimization	Realistic load models
Parker et al. (1996)	Parker CJ et al.	1996	Voltage collapse	DSTATCOM	Location & size	Static	Mixed-Integer Optimization	Robustness
Araby et al. (2002)	Araby EEE et al.	2002	Voltage collapse	GUPFC & STATCOM	Location, size & type	Static	Mixed-Integer Optimization	Hybrid techniques
Xie et al. (2003)	Xie H et al.	2003	System stability	IPFC	Location, size & type	Static	Mixed-Integer Optimization	Environmental friendliness
Abdel-Magid et al. (2000)	Abdel-Magid YL et al.	2000	System stability	HPFC	Location, size & type	Static	Mixed-Integer Optimization	Realistic load models
Mihilic et al. (1996)	R. Mihilic et al.	1996	System stability	TCSC & DSTATCOM	Location, size & type	Static	Mixed-Integer Optimization	Environmental friendliness
Ghyugyi et al. (1999)	L. Gyugyi et al.	1999	System stability	DSTATCOM	Location, size & type	Static	Mixed-Integer Optimization	Environmental friendliness
Wildenhues et al. (2014)	Wildenhues et al.	2014	System stability	GUPFC & STATCOM	Location & size	Static	Mixed-Integer Optimization	Environmental friendliness
Paramasivam et al. (2013)	Paramasivam et al.	2013	System stability	IPFC	Location & size	Static	Mixed-Integer Optimization	Hybrid techniques
Deng et al. (2018)	Zhuoming Deng et al.	2018	System stability	HPFC	Location & size	Static	Mixed-Integer Optimization	Hybrid techniques
Qader (2015)	Qader M.	2015	Power quality	TCSC & DSTATCOM	Location & size	Static	Mixed-Integer Optimization	Realistic load models
Orfano Gianni and Bacher (2003)	T. Orfano Gianni et al.	2003	Power quality	UPQC & DVR	Location & size	Static	Mixed-Integer Optimization	Robustness
Kumar et al. (2007a)	Kumar BK et al.	2007	System oscillations	UPFC & STATCOM	Location & size	Static	Mixed-Integer Optimization	Hybrid techniques

simulation method calculates the model different times, each time using different randomly selected values.

Intelligent programming method: Artificial intelligence method also known as machine intelligence is demonstrated by machines in contrast to the natural intelligence. Computer science engineering defines AI method is a device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals. Artificial intelligence is applied, when a machine functions that humans associate with other human minds, such as “learning” and “problem solving”.

Artificial bee colony algorithm: ABC method is an optimization algorithm based on the intelligent behavior of honey bee swarm, which was proposed by Dervis Karaboga in 2005. In this model, the colony consists of three groups of bees, employed bees, on-lookers and scouts. There is only one artificial bee for each food source. The number of bees in the colony is equal to the number of food sources around the hive. The bee whose food source has been abandoned starts to search for finding a new food source.

Artificial neural network method: Neural network is not an algorithm, but a connection for many different learning algorithms to work together and process complex data inputs. Such systems learn to perform various tasks by considering examples, generally without programmed with any task specific rules. ANN method is based on a collection of connected units or nodes called artificial neurons, which mainly model the neurons in a biological brain. Each connection just is like the synapses in a biological brain, which can transmit a signal from one artificial neuron to another.

Fuzzy linear programming: Fuzzy linear programming problem has many different applications and various methods have been proposed for solving this problem. Some researchers presented two new methods to solve FLP. This scheme is presented results from the aspects of performance and computing efficiency.

Therefore comparison between the two methods for the problem shows a remarkable solution and the new model is more reliable in the point of view of optimality.

Particle swarm optimization method: PSO method is used to optimize a problem by improve a candidate solution with regard to a given measure of quality. Each particle is influenced by its best known position but is also guided toward the best known positions in the search-space. The algorithm is simplified and observed to performing optimization. The PSO algorithm given by having a population (called a swarm) of candidate solutions (called particles). These particles are moved around in the search-space according to a few simple formulas.

2.4. Hybrid techniques

The hybrid techniques for enhancement of system performances by different types of FACTS controllers in power systems with static and realistic load models are discussed as follows

Energy approach method: These methods are based on linear behavior and conservation of energy, i.e. the work done by external forces equals the energy stored in the structure under load. Energy management includes planning and operation of energy production and energy consumption units. Objectives are resource conservation, climate protection and cost savings, while the users have permanent access to the energy they need.

Active Control Technique: The active power control is implemented by means of an adjustable speed machine, which is primarily used as a synchronous condenser, but includes a fly-wheel for short term active power injection into the system. This adjustable speed machine can support the power system to avoid voltage collapse or excessive voltage dips by compensating both active and reactive power supply to the system immediately after a disturbance.

Table 4
A survey on artificial intelligence computational techniques for enhancement of system performances by using different types of FACTS controllers in power systems with static and realistic load models.

Ref. No.	Author	Year	Power system performances	FACTS controllers used	Parameters for optimization	Load models	Techniques	Future work
Dhas et al. (2000)	P. K. Dash et al.	2000	System stability	GUPFC	Location & size	Static	GA	Environmental friendness
Hazhra et al. (2007)	Jagabondhu Hazra et al.	2007	Power accuracy	SVC & SSSC	Location & size	Static	GA	Environmental friendness
Yashida et al. (2000b)	H. Yoshida et al.	2000	System reliability	DSTATCOM	Location, size & type	Static	GA	Practical implementation
Vijaykumar and Kumudini Devi (2007)	K. Vijaykumar et al.	2007	System stability	GUPFC & STATCOM	Location, size & type	Static	GA	Practical implementation
Chandrasekaran et al. (2005-2009)	K. Chandrasekaran et al.	2009	Power accuracy	IPFC	Location, size & type	Static	GA	Hybrid techniques
Yang et al. (2007)	Guang Ya Yang et al.	2000	System stability	HPFC	Location, size & type	Static	GA	Environmental friendness
Accha et al. (2004)	E. Acha et al.	2004	System reliability	TCSC & DSTATCOM	Location, size & type	Static	GA	Practical implementation
Morris et al. (2003)	Stella Morris et al.	2003	Power accuracy	DSTATCOM	Location & size	Static	GA	Robustness
Bakirtzis et al. (2002)	A. G. Bakirtzis et al.	2002	System stability	GUPFC & STATCOM	Location & size	Static	GA	Robustness
Vijaykumar and Kumudini Devi (2008)	K. Vijaykumar et al.	2008	Power accuracy	IPFC	Location & size	Static	GA	Robustness
Priti et al. (2011)	V. A. Preethi et al.	2011	System stability	HPFC	Location & size	Static	GA	Practical implementation
Tukharam et al. (1996)	B. D. Thukaram et al.	1996	System stability	TCSC & DSTATCOM	Location & size	Static	GA	Hybrid techniques
Gerbhex et al. (2001)	S. Gerbex et al.	2001	Power quality	UPQC	Location & size	Static	GA	Environmental friendness
Vijaya kumar and Kumudini devi (2007)	Vijaya kumar K et al.	2007	System stability	UPFC & STATCOM	Location, size & type	Static	GA	Environmental friendness
Abdel-Magid et al. (1999)	Abdel-Magid YL et al.	1999	System stability	GUPFC	Location, size & type	Static	GA	Hybrid techniques
Pandey and Gupta (2018)	Rajendra K. Pandey et al.	2018	Power loss reduction	SVC & SSSC	Location, size & type	Static	Symbiotic organism search (SOS) algorithm	Robustness
Verbic and Gubina (2004)	Gregor Verbic et al.	2004	System stability	DSTATCOM	Location & size	Static	Symbiotic organism search (SOS) algorithm	Practical implementation
Dillon (1991)	T. S. Dillon et al.	1991	System stability	GUPFC & STATCOM	Location & size	Static	Symbiotic organism search (SOS) algorithm	Practical implementation
Pandha and Ardhil (2007)	Sidhartha Panda Et al.	2007	Power loss reduction	IPFC	Location & size	Static	Symbiotic organism search (SOS) algorithm	Environmental friendness
Lima et al. (2003)	Flavio G. M. Lima et al.	2003	System stability	HPFC	Location & size	Static	Computational Simulations	Practical implementation
Vijaykumar and Kumudini Devi (0000)	K. Vijayakumar et al.	2007	Power loss reduction	TCSC & DSTATCOM	Location, size & type	Static	Computational Simulations	Robustness
Sadhegh et al. (2005)	Sadegh, M. Outkati et al.	2005	Power accuracy	DSTATCOM	Location, size & type	Static	Computational Simulations	Hybrid techniques
Renzh et al. (1999)	B. A. Renz et al.	1999	System stability	GUPFC & STATCOM	Location & size	Static	Computational Simulations	Hybrid techniques
Mori and Goto (2000)	H. Mori et al.	2000	System stability	IPFC	Location & size	Static	Tabu search based method	Environmental friendness
Etingov et al. (2007)	Pavel Etingov et al.	2007	Power loss reduction	HPFC	Location & size	Static	Monte Carlo Simulation	Robustness
Blanco et al. (2011)	Blanco G et al.	2011	Power accuracy	TCSC & DSTATCOM	Location & size coordination	Static	Monte Carlo Simulation	Hybrid techniques

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Passivity method: Passivity method is a property used in a various engineering disciplines, but most commonly found in analog electronics and control systems. A passive component depending

on field may be either a component that consumes but does not produce energy or a component that is incapable of power gain.

Hybrid technique: A combination of two or more computational **techniques** which provide greater advantages than individual

Table 4 (continued).

Ref. No.	Author	Year	Power system performances	FACTS controllers used	Parameters for optimization	Load models	Techniques	Future work
Shadhegh et al. (2005)	Sadegh et al.	2005	Power accuracy	UPQC & DVR	Location & size	Static	Intelligent Programming	Practical implementation
Chang and Huang (1997b)	Chang CS et al.	1997	Power system stability	UPFC & STATCOM	Location & size	Static	Intelligent Programming method	Hybrid technique
Mohamad Idris et al. (2010)	R.Mohamad Idris et al.	2010	System stability	GUPFC & STATCOM	Location & size	Static	Artificial bee colony algorithm	Hybrid techniques
Shyh and Xian (2013)	Shyh JH et al.	2013	Power quality	IPFC	Location & size coordination	Static	Artificial bee colony algorithm	Hybrid techniques
Feurthe Es-hquivel and Accha (1997)	C. R. Feurte Esquivel	1997	Power quality	HPFC	Location & size	Static	ANN method	Practical implementation
Kheib et al. (1995)	A. A. El-Keib	1995	Power quality	TCSC & DSTATCOM	Location & size	Static	ANN method	Robustness
Mozhgan (2012)	Mozhgan Balaver	2012	System stability	UPQC	Location & size	Static	ANN method	Hybrid techniques
Zeynelgil and Demiroren (2002)	Zeynelgil HL et al.	2002	Power quality	UPFC & STATCOM	Location & size coordination	Static	ANN method	Practical implementation
Nguyen et al. (2008)	T.T. Nguyen et al.	2008	System stability	HPFC	Location & size	Static	ANN method	Hybrid technique
Daskh and Paanda (2000)	Dash PK et al.	2000	System stability	TCSC & DSTATCOM	Location & size	Static	ANN method	Environmental friendness
Nar et al. (1990)	K. S. Narendra et al.	1990	System stability	UPQC	Location & size coordination	Static	ANN method	Hybrid technique
Tomsovcics (1992)	K. Tomsovic et al.	1992	Power quality	UPFC & STATCOM	Location & size	Static	Fuzzy linear programming	Practical implementation
Cai and Erlich (2006)	Cai LJ et al.	2006	Power quality	GUPFC & STATCOM	Location & size	Static	Fuzzy linear programming	Robustness
Venkatesh et al. (1999)	Venkatesh B et al.	1999	Voltage collapse	IPFC	Location & size	Static	Fuzzy linear programming	Robustness
Mishra et al. (2000)	Mishra S et al.	2000	Power quality	HPFC & DVR	Location & size coordination	Static	Fuzzy linear programming	Practical implementation
Daas et al. (2000)	P.K. Dash et al.	2000	Power quality	TCSC & DSTATCOM	Location & size	Static	Fuzzy linear programming	Environmental friendness
Limchiron et al. (1998)	S. Limyingcharone et al.	1998	System stability	UPQC	Location & size	Static	Fuzzy linear programming	Practical implementation
Benabidh et al. (2009)	R. Benabid et al.	2009	Power accuracy	UPFC & STATCOM	Location & size coordination	Static	PSO method	Robustness
Panda and Ardil (2008)	Panda S et al.	2008	System stability	SVC	Location & size	Static	PSO method	Practical implementation
Rashidi and Hawary (2009)	Rashidi MRA	2009	System stability	TCSC	Location & size	Static	PSO method	Robustness
Abido (2002)	Abido MA et al.	2002	System stability	HPFC	Location & size	Static	PSO method	Environmental friendness
Yoshida et al. (2000)	Yoshida H, Kawata et al.	2000	System protection	UPFC	Location & size coordination	Static	PSO method	Practical implementation
Kannan et al. (2004)	Kannan S et al.	2004	Power quality	SVC	Location & size coordination	Static	PSO method	Hybrid techniques
Yashida et al. (2000a)	H.Yoshida et al.	2000	System security	STATCOM	Location & size coordination	Static	PSO method	Robustness
Shayeghi et al. (2009)	Shayeghi H et al.	2009	Power quality	UPFC	Location & size coordination	Static	PSO method	Environmental friendness

techniques and improve data analysis is known as Hybrid Technique. A hybrid technique is used for improving the voltage stability of a given system with optimal power flow solution using FACTS device installation.

Pole placement techniques: Pole placement method is a controller design method, in which you determine the places of the closed loop system poles on the complex plane by setting a controller gain. Poles describe the behavior of linear dynamical systems. Thus you can decide on where the closed loop poles should be and then force them to be there by designing a feedback control system via pole placement method where you choose a controller gain that places the poles on their desired locations.

Graph search algorithm: Graph search algorithms specify an order to search through the nodes of a graph. We start from the source node and keep searching until we find the target node.

Those graphs contain nodes that we have seen but have not explored yet. Each iteration, we take a node off the frontier and add its neighbors to the frontier. A graph search technique visits every node exactly one in a systematic manner.

Decomposition coordination methods: Decomposition methods solve a boundary value problem by splitting it into smaller boundary value problems on sub domains and iterating to coordinate the solution between adjacent sub domains. A coarse problem with one or few unknowns per sub domain is used to further coordinate the solution between the sub domains globally. Several hours per time step is an average sequential run time, therefore, parallel computing is a necessity. Decomposition methods embody large potential for a parallelization of the finite element methods, and serve a basis for distributed parallel computations.

Table 5
A survey on hybrid techniques for enhancement of system performances by different types of FACTS controllers in power systems with static and realistic load models.

Ref. No.	Author	Year	Power system performance	FACTS controllers used	Parameters for optimization	Load models	Techniques	Future work
Satheesh and Manigandan (2013)	Satheesh A et al.	2013	System stability	UPQC	Location & size	Static	ABC and ANN	Practical implementation
Chung and Li (2001)	Chung TS et al.	2001	System stability	UPFC & STATCOM	Location & size	Static	GA and OPF	Robustness
Phalliate et al. (1997)	L.A.S. Pilotto et al.	1997	System reliability	SVC	Location, size & type	Static	GA and OPF	Practical implementation
Mustafa and Chiew (2008)	Mohd Wazir Mustafa et al.	2008	System protection	TCSC	Location, size & type	Static	GA and OPF	Practical implementation
Subhanga and Kulkaarni (2002)	K. N. Shubhanga et al.	2002	System stability	HPFC	Location, size & type	Static	GA and OPF	Realistic load models
Gerbex et al. (2001)	S.Gerbex et al.	2001	System reliability	UPFC	Location, size & type	Static	GA and OPF	Robustness
Xu and Ahmad Zaid (1995)	L Xu et al.	1995	Voltage collapse	SVC	Location, size & type	Static	GA and OPF	Practical implementation
Liu et al. (2006)	Shu Liu et al.	2006	System reliability	STATCOM	Location, size, type & coordination	Static	GA and OPF	Environmental friendliness
Abhou Elaa et al. (2010)	A.A. Abou El-Elaa et al.	2010	System reliability	UPFC	Location, size & type	Static	GA and OPF	Robustness
Mithulantan et al. (2003)	N. Mithulananthan et al.	2003	Reliability and efficiency	UPQC	Location, size & type	Static	GA and OPF	Practical implementation
Mahdad et al. (2009)	B. Mahdad et al.	2009	Power quality	UPFC & STATCOM	Location, size & type	Static	GA and OPF	Robustness
Ippolito et al. (2006)	L. Ippolito et al.	2006	Reliability and efficiency	TCSC	Location, size, type & coordination	Static	GA and OPF	Practical implementation
Chatterji et al. (2007)	D. Chatterjee and Arindam Ghosh	2007	Power system stability	TCSC	Location, size & type	Static	OPF and SA	Environmental friendliness
So et al. (2005)	Ping Lam So et al.	2005	System stability	HPFC	Location, size & type	Static	OPF and SA	Practical implementation
Jeevarathinam (2006)	B. Jeevarathinam et al.	2006	Voltage collapse	UPQC	Location, size & type	Static	GA and FZ	Robustness
Li et al. (2012b)	Yong Li et al.	2012	System protection	SVC	Location, size, type & coordination	Static	GA and FZ	Environmental friendliness
Alamhelu et al. (2008)	S.M. Alamelu et al.	2008	System protection	STATCOM	Location, size & type	Static	SA and EP	Robustness
Ko et al. (2009)	Chia-Nan Ko et al.	2009	System reliability	UPFC	Location, size & type	Static	PSO And MINLP	Robustness
Chung et al. (2003)	C. Y. Chung et al.	2003	Reliability and efficiency	DSTATCOM	Location, size & type	Static	SA and MILP	Environmental friendliness
Chan-dra sekarani et al. (2009)	Chandra sekarani K et al.	2009	Power quality	DVR & STATCOM	Location, size, type & coordination	Static	OPF and PSO	Practical implementation
Niknam et al. (2012)	Niknam T et al.	2012	System stability	Hybrid DSTATCOM	Location, size & type	Static	OPF and PSO	Practical implementation
Rezaei and Karami (2013)	Rezaei AM et al.	2013	Power quality	UPFC	Location, size & type	Static	ABC and OPF	Environmental friendliness
Kimkhratug (2012)	P. Kumkratug	2012	System stability	HPFC	Location, size & type	Static	OPF and FZ	Environmental friendliness
Nurzian et al. (1996)	M. Noorzian et al.	1996	Power quality	UPFC	Location, size, type & coordination	Static	OPF and FZ	Robustness

Whale optimization algorithm: Whale Optimization Algorithm is a optimization algorithm for the hunting mechanism of humpback whales in nature. According to Hof and Van Der Gucht, whales have common cells in certain areas of their brains similar to those of human called spindle cells. Spindle cells make us distinct from other creatures. Whales have twice number of these cells than an adult human which is the main cause of their smartness. It has been observed that whales (mostly killer whales) are able to develop their own dialect as well. One of the biggest baleen whales is humpback whales. The most interesting thing about the humpback whales is their special hunting method. This foraging behavior is called bubble-net feeding method.

Gray Wolf Optimizer: The GWO algorithm has the leadership hierarchy and hunting mechanism of gray wolves in nature. There are three main steps of hunting, searching for prey, encircling prey and attacking prey are implemented. The algorithm is then benchmarked on 29 well-known test functions, and the results are verified by a comparative study with Particle Swarm Optimization, Gravitational Search Algorithm, Differential Evolution, Evolutionary Programming and Evolution Strategy.

Meta-heuristic algorithm: A Meta-heuristic is a procedure or heuristic designed to find, generate or select a heuristic (partial search algorithm) that may provide a sufficiently good solution to an optimization problem with incomplete information

Table 6

A survey on other techniques for enhancement of system performances by different FACTS controllers in power systems with static and realistic load models.

Ref. No.	Author	Year	Power system performance	FACTS controllers used	Parameters for optimization	Load models	Techniques	Future work
Hoque (2004)	M. H. Haque	2004	Power quality	UPFC	Location & size	Static	Energy approach	Environmental friendness
Hoque (2008)	M. H. Haque	2008	Active power loss	SVC	Location & size	Static	Energy approach	Practical implementation
Wenzel and Leibfried (2012)	Timo Wenzel et al.	2012	System reliability	STATCOM	Location, size & type	Static	Energy approach	Environmental friendness
Goksu et al. (2014)	Omer Goksu et al.	2014	System reliability	UPFC	Location, size & type	Static	Energy approach	Robustness
Pillottho et al. (1997)	L. A. S. Pilotto et al.	1997	Improve the reliability of supply	UPQC	Location, size & type	Static	Energy approach	Practical implementation
Yeu et al. (2001)	X. Yu et al.	2001	System reliability	UPFC & STATCOM	Location, size & type	Static	Energy approach	Practical implementation
Kundur and Morison (1997)	P. Kundur et al.	1997	System stability	TCSC	Location, size & type	Static	Energy approach	Environmental friendness
Zhou (1993)	E. Z. Zhou et al.	1993	System stability	TCSC	Location, size, type & coordination	Static	Energy approach	Environmental friendness
Kobayashi et al. (2003)	K. Kobayashi et al.	2003	Voltage stability	HPFC	Location, size & type	Static	Energy approach	Practical implementation
Mihalic and Zhunko (1996)	R. Mihalic et al.	1996	System stability	UPQC	Location, size & type	Static	Energy approach	Robustness
Farsangi et al. (2007)	Farsangi MM et al.	2007	Power quality	SVC	Location, size & type	Static	Energy approach	Hybrid techniques
Niaki and Irhavani (1996)	A. Nabavi-Niaki et al.	1996	Power quality	STATCOM	Location, size, type & coordination	Static	Energy approach	Environmental friendness
Manshour et al. (1994)	Y. Mansour et al.	1994	System stability	UPFC	Location, size & type	Static	Energy approach	Environmental friendness
Khederzadeh and Ghorbani (2012a)	Khederzadeh et al.	2012	System stability	DSTATCOM	Parameters for Optimization	Static	Energy approach	Hybrid techniques
Aghaei et al. (2016)	Aghaei J et al.	2016	System stability	DVR & STATCOM	Location & size	Static	Energy approach	Environmental friendness
Angquhuist et al. (1993)	L. Angquist et al.	1993	System reliability	Hybrid DSTATCOM	Location & size	Static	Energy approach	Environmental friendness
Azhbe et al. (2005)	V. Abe et al.	2005	Power system stability	UPFC	Location, size & type	Static	Energy approach	Robustness
Khederzadeh and Ghorbani (2012b)	Mojtaba Khederzadeh et al.	2012	Power System protection	UPFC	Location, size & type	Static	Active control technique	Robustness
Gonzalez et al. (2010)	Juan Miguel Gonzalez et al.	2010	Power quality	SVC	Location, size & type	Static	Active control technique	Hybrid techniques
Shong et al. (2010)	Wenchao Song et al.	2010	Active power loss	STATCOM	Location, size & type	Static	Active control technique	Environmental friendness
Baek et al. (2013)	Seung-Mook Baek et al.	2013	Power System protection	UPFC	Location, size & type	Static	Active control technique	Environmental friendness
Guo et al. (2018b)	C. Guo et al.	2018	System stability	UPQC	Location, size, type & coordination	Static	Active control technique	Environmental friendness
Kanan et al. (2004)	S. Khannan et al.	2004	System stability	UPFC & STATCOM	Location, size & type	Static	Active control technique	Environmental friendness
Edris (2000)	Edris A et al.	2000	System improvement	TCSC	Location, size & type	Static	Active control technique	Environmental friendness
Whang and Shwift (1996)	H. F. Wang et al.	1996	Controlling of power system	TCSC	Location, size & type	Static	Active control technique	Robustness
Paphic et al. (1997)	I. Papic et al.	1997	System stability	HPFC	Location, size, type & coordination	Static	Active control technique	Robustness
Kumar et al. (2007b)	B. K. Kumar et al.	2007	Controlling of power system	UPQC	Location, size & type	Static	Active control technique	Robustness
Reis and Maciel Barbosa (2006)	Claudia Reis et al.	2006	Power quality	SVC	Parameters for Optimization	Static	Active control technique	Hybrid techniques
Mohsen et al. (2013)	Mohsen G et al.	2013	System stability	STATCOM	Location & size	Static	Active control technique	Practical implementation
Zenghyu et al. (2000)	Huang Zhengyu et al.	2000	Power quality	UPFC	Location & size	Static	Active control technique	Hybrid techniques
Venkataraman and Johnson (2002)	G. Venkataraman et al.	2002	System stability	DSTATCOM	Location, size & type	Static	Active control technique	Practical implementation

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Table 6 (continued).

Ref. No.	Author	Year	Power system performance	FACTS controllers used	Parameters for optimization	Load models	Techniques	Future work
Mancilla David and Venkataraman (2000)	F. Mancilla-David et al.	2005	Power quality	DVR & STATCOM	Location, size & type	Static	Active control technique	Hybrid techniques
Khederzadeh and Sidhu (2006)	Khederzadeh et al.	2006	Power quality	Hybrid DSTATCOM	Location, size & type	Static	Active control technique	Robustness
Pilotto et al. (1997)	Pilotto LAS et al.	1997	Power quality	UPFC	Location, size & type	Static	Active control technique	Robustness
Canizares et al. (1999)	Claudio a. Canizares et al.	1999	Voltage collapse	DSTACOM	Location, size & type	Static	Active control technique	Realistic load models
Park and Baek (2012)	Ji-Ho Park et al.	2012	Power System protection	HPFC	Location, size, type & coordination	Static	Active control technique	Practical implementation
Noruzian et al. (1999)	M. Noroozian et al.	1999	Power quality	UPFC	Location, size & type	Static	Active control technique	Robustness
Shukla and Mili (2017)	Srivats Shukla et al.	2017	System protection	DSTATCOM	Location, size & type	Static	Active control technique	Practical implementation
Yorinno et al. (2003)	Naoto Yorino et al.	2003	Voltage collapse	DVR & STATCOM	Location, size & type	Static	Passivity method	Robustness
Gui et al. (2016)	Yonghao Gui et al.	2016	System protection	Hybrid DSTATCOM	Location, size, type & coordination	Static	Passivity method	Environmental friendliness
Zheao et al. (1998)	Q. Zhao et al.	1998	Controlling Of Power Loss	UPFC	Location, size & type	Static	Passivity method	Practical implementation
Sauer and Pai (1990)	Sauer, P.W. et al.	1990	Voltage stability	DSTACOM	Parameters for Optimization	Static	Passivity method	Practical implementation
Conejo et al. (2006)	A. J. Conejo et al.	2006	Power system stability	HPFC	Location & size	Static	Passivity method	Practical implementation
Chang et al. (2009a)	Chang B et al.	2009	System stability	DVR	Location & size	Static	Passivity method	Environmental friendliness
Rhao et al. (2000)	P. Rao et al.	2000	System stability	TCSC	Location, size & type	Static	Passivity method	Environmental friendliness
Kundhur et al. (2004)	P. Kundur et al.	2004	System stability	DSTATCOM	Location, size & type	Static	Passivity method	Hybrid techniques
Potamianakis and Vournas (2006)	Potamianakis et al.	2006	System stability	DVR & STATCOM	Location, size & type	Static	Passivity method	Environmental friendliness
Kejani and Gholipour (2017)	Mohsen Basiri-Kejani et al.	2017	Power quality	Hybrid DSTATCOM	Location, size & type	Static	Hybrid technique	Practical implementation
Hu et al. (2018)	P. Hu et al.	2018	Power quality	UPFC	Location, size & type	Static & realistic	Hybrid technique	Practical implementation
Dhong et al. (0000)	Z. Y. Dong et al.	1999	System stability	DSTACOM	Location, size, type & coordination	Static	Hybrid technique	Robustness
Hajagos and Danai (1998)	Hajagos L et al.	1998	System stability	HPFC	Location, size & type	Static	Hybrid technique	Hybrid techniques
Kumkrahug et al. (2003)	P. Kumkratug et al.	2003	Power quality	DVR	Location, size & type	Static	Hybrid technique	Hybrid techniques
Vahidna et al. (2016)	A. Vahidnia et al.	2016	System stability	TCSC	Location, size & type	Static	Hybrid technique	Practical implementation
Faaershangi et al. (2007)	M. M. Farsangi et al.	2007	Power system stability	DSTATCOM	Location, size, type & coordination	Static	Pole placement techniques	Hybrid techniques
Kessel and Ghlavitsch (1986)	P. Kessel et al.	1986	System stability	DVR & STATCOM	Location, size & type	Static	Pole placement techniques	Robustness
Thukaram et al. (2005)	Thukaram et al.	2005	System security	Hybrid DSTATCOM	Parameters for Optimization	Static	Pole placement techniques	Robustness
Ahsae and Sadeh (2011)	Ahsae MG et al.	2011	System stability	UPFC	Location & size	Static	Pole placement techniques	Hybrid techniques
Madhtharad et al. (2005)	C. Madhtharad et al.	2005	System protection	DSTACOM	Location & size	Static	Graph search algorithm	Environmental friendliness
Niaki and Irhvani (1996)	A. N. Niaki et al.	1996	Power quality	HPFC	Location, size & type	Static	Graph search algorithm	Hybrid techniques
Larshen et al. (1995)	E. V. Larsen et al.	1995	Power swing	DVR	Location, size & type	Static	Graph search algorithm	Hybrid techniques
Olivheira (1994)	S. E. M. De Oliveira	1994	System stability	TCSC	Location, size & type	Static	Decomposition coordination methods (DCM)	Robustness
Whei et al. (2005)	X. Wei et al.	2005	System stability	TCPAR	Location, size & type	Static	Decomposition coordination methods (DCM)	Robustness

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Table 6 (continued).

Ref. No.	Author	Year	Power system performance	FACTS controllers used	Parameters for optimization	Load models	Techniques	Future work
Hua et al. (2019)	Pengfei Hua et al.	2019	Power quality	GUPFC	Location, size & type	Static	Hybrid technique	Hybrid techniques
Sahu et al. (2017)	Preeti Ranjan Sahu et al.	2017	Power system stability	GIPFC	Location, size, type & coordination	Static	Whale optimization algorithm	Practical implementation
Ladhumaor et al. (2017a)	Dilip P. Ladumor et al.	2017	Power quality	DSTACOM	Location, size & type	Static	Gray Wolf Optimizer	Environmental friendliness
Ladhumaor et al. (2017b)	Dilip P. Ladumor et al.	2017	System stability	HPFC	Location, size & type	Static	Meta-heuristic algorithm	Hybrid techniques
Wildheunhues et al. (2015)	Sebastian Wildenhues et al.	2015	Power quality	DVR	Location, size & type	Static	Meta-heuristic algorithm	Robustness
Kuyu and Vatansever	Yigit Cagatay Kuyu et al.	2018	Controlling Of Power Loss	TCSC	Location, size, type & coordination	Static	Salp Swarm Optimizer	Practical implementation
Hamour et al.	Hanan Hamour et al.	2018	Controlling Of Power Loss	TCPAR	Location, size & type	Static	Grasshopper Optimization Algorithm	Environmental friendliness
George et al.	Thomas George et al.	2018	Controlling Of Power Loss	GUPFC	Location, size & type	Static	Ant Lion Optimization Technique	Hybrid techniques
Nayak et al.	Niranjan Nayak et al.	2016	System stability	GIPFC	Location, size & type	Static	Spider Monkey Optimization	Hybrid techniques
Hazrati et al.	Garima Hazrati et al.	2016	Power quality	UPQC	Location, size & type	Static	Spider Monkey Optimization	Robustness
Kaur et al.	Avinash Kaur et al.	2017	Power quality	DVR	Location & type	Static	Spider Monkey Optimization	Environmental friendliness
Behera et al. (2018)	Tanmaya Kumar Behera et al.	2018	Controlling of Power Loss	TCSC	Location, size & type	Static	Spider Monkey Optimization	Hybrid techniques

or limited computation capacity. Meta-heuristics sample is a set of solutions which is too large for completely sampled. Meta-heuristics may make few assumptions about the optimization problem being solved, and so they may be usable for many problems.

Salp Swarm Optimizer: Salp Swarm Algorithm and Multi objective Salp Swarm Algorithm are used for solving optimization problems with single and multiple objectives. The main inspiration of Salp Swarm Algorithm and Multi objective Salp Swarm Algorithm is the swarming behavior of salps when navigating and foraging in oceans. Salp Swarm Algorithm and Multi objective Salp Swarm Algorithm are tested on some mathematical optimization functions to observe and confirm their effective behaviors in finding the optimal solutions for optimization problems. The result shows that the Salp Swarm Algorithm is able to improve the initial random solutions effectively and converge towards the optimum. The results of Multi objective Salp Swarm Algorithm show that this algorithm can approximate optimal solutions with high convergence and coverage.

Grasshopper Optimization Algorithm: Grasshopper is insects. They are considered a pest due to their damage to crop production and agriculture. So grasshoppers are rarely seen individually in nature and they join in one of the largest swarm of all creatures. The swarm size may be of continental scale and a nightmare for farmers. The main objective of the grasshopper swarm is that the swarming behavior is found in both nymph and adulthood. Millions of nymph grasshoppers jump and move like rolling cylinders. In their path, they eat almost all vegetation. After this behavior, when they become adult, they form a swarm in the air. This is how grasshoppers migrate over large distances. In contrast, long-range and abrupt movement is the essential feature of the swarm in adulthood.

Ant Lion Optimization Technique: The Ant Lion Optimization (ALO) algorithm mimics the hunting mechanism of ant lions in nature. The proposed algorithm is described in three phases. First one a set of 19 mathematical functions is employed to test different characteristics of ALO. Another one are three classical

engineering problems are solved by ALO. And last, the shapes of two ship propellers are optimized by ALO as challenging real problems. So after the calculations test functions prove that the proposed algorithm is able to provide very accurate results in terms of improved exploration, exploitation, and convergence. The ALO algorithm also finds superior optimal designs for the majority of classical engineering problems, showing that this algorithm has merits in solving constrained problems with diverse search spaces.

Spider monkey optimization: In this technique, a new approach for optimization is proposed by modeling the social behavior of spider monkeys. Spider monkeys have been categorized as fission–fusion social structure based animals. The animals which follow fission–fusion social systems, initially work in a large group and based on need after some time, they divide themselves in smaller groups led by an adult female for foraging. Therefore, the proposed strategy broadly classified as inspiration from the intelligent foraging behavior of fission–fusion social structure based animals.

3. Summary of paper

The summary of this article from conventional techniques, optimization techniques, artificial computational intelligence, hybrid and current techniques for enhancement of system performances by different FACTS controllers in power systems with static and realistic load models viewpoints are discussed in Sections 3.1–3.5, subsequently and comparison between these techniques are also discussed in Section 3.6, subsequently.

3.1. Conventional techniques

Table 7 and Fig. 1, shows the summary of this article from conventional optimization techniques for enhancement of system performances by different FACTS controllers in power systems with static and realistic load models viewpoints.

% Literatures reviewed from conventional optimization techniques viewpoints

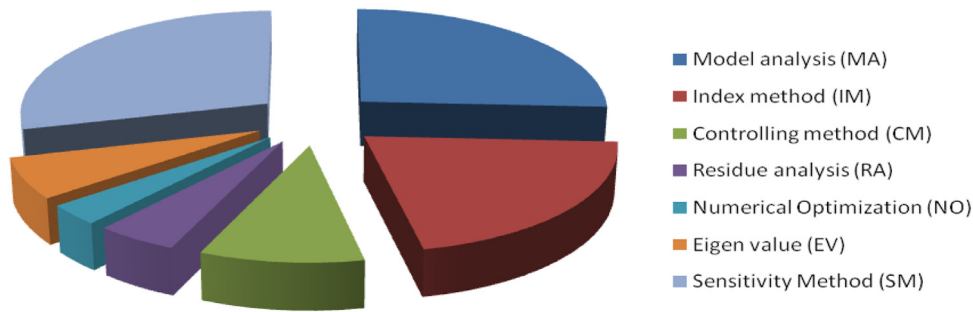


Fig. 1. % Literature reviewed from conventional optimization techniques viewpoints.

Table 7

Conventional optimization techniques.

Conventional techniques	Literatures reviewed	% Literatures reviewed
Model analysis (MA)	16	25.81
Index method (IM)	13	20.97
Controlling method (CM)	6	9.68
Residue analysis (RA)	3	4.84
Numerical Optimization (NO)	2	3.23
Eigen value (EV)	4	6.45
Sensitivity Method (SM)	18	29.03

Table 8

Optimization techniques.

Optimization techniques	Literatures reviewed	% Literatures reviewed
Linear programming (LP)	6	7.60
Mixed-Integer Nonlinear Programming (MINLP)	6	7.60
Stochastic Load Flow (SLF)	5	6.33
Adaptive control law (ACL)	2	2.53
Analytical Approach (AA)	11	13.92
Dynamic Programming (DP)	2	2.53
OPF method	16	20.25
Modified Mixed-Integer Non-Linear Programming (MMINLP)	31	39.24

Fig. 1, it is concluded that the MA, IM, CM, RA, NO, EV and SM are 25.81%, 20.97%, 9.68%, 4.84%, 3.23%, 6.45% and 29.03% literatures reviewed from conventional optimization techniques viewpoints, respectively.

3.2. Optimization techniques

Table 8 and Fig. 2, shows the summary of this article from optimization techniques for enhancement of system performances by different FACTS controllers in power systems with static and realistic load models viewpoint.

Fig. 2, it is concluded that the LP, MINLP, SLF, ACL, AA, DP, OPF and MMINLP are 7.60%, 7.60%, 6.33%, 2.53%, 20.25% and 39.24% literatures are reviewed from optimization techniques viewpoint, respectively.

Table 9

Artificial intelligence computational techniques.

AI techniques	Literatures reviewed	% Literatures reviewed
GA	15	29.41
Symbiotic organism search (SOS) algorithm	4	7.84
Computational Simulations (CS)	4	7.84
Tabu search based method (TS)	1	1.96
Monte Carlo Simulation (MCS)	2	3.92
Intelligent Programming (IP)	2	3.92
Artificial bee colony algorithm (ABC)	2	3.92
ANN method	7	13.73
Fuzzy linear programming (FZ)	6	11.77
PSO	8	15.69

3.3. Artificial intelligence computational techniques

Table 9 and Fig. 3, shows the summary of this article from artificial intelligence computational techniques for enhancement of system performances by different FACTS controllers in power systems with static and realistic load models viewpoint.

Fig. 3, it is concluded that the GA, SOS, CS, TS, MCS, IP, ABC, ANN, FZ, LP and PSO method are 29.41%, 7.84%, 7.84%, 1.96%, 3.92%, 3.92%, 3.92%, 13.73%, 11.77% and 15.69% literatures are reviewed from AI techniques viewpoint, respectively.

3.4. Hybrid techniques

Table 10 and Fig. 4, shows the summary of this article from hybrid techniques for enhancement of system performances by different FACTS controllers in power systems with static and realistic load models viewpoint.

Fig. 4, it is concluded that the hybrid of ABC and ANN, hybrid of GA and OPF, hybrid of OPF and SA, hybrid of GA and FZ, hybrid of SA and EP, hybrid of PSO And MINLP, hybrid of SA and MILP, hybrid of OPF and PSO, hybrid of ABC and OPF, hybrid of Lyapunov Theory and Fuzzy Logic and hybrid of OPF and Fuzzy Logic are 4.17%, 45.83%, 8.33%, 8.33%, 4.17%, 4.17%, 4.17%, 4.17%, 8.33%, 4.17% and 8.33% literatures are reviewed from hybrid technique viewpoint, respectively.

% Literatures reviewed from optimization techniques viewpoints

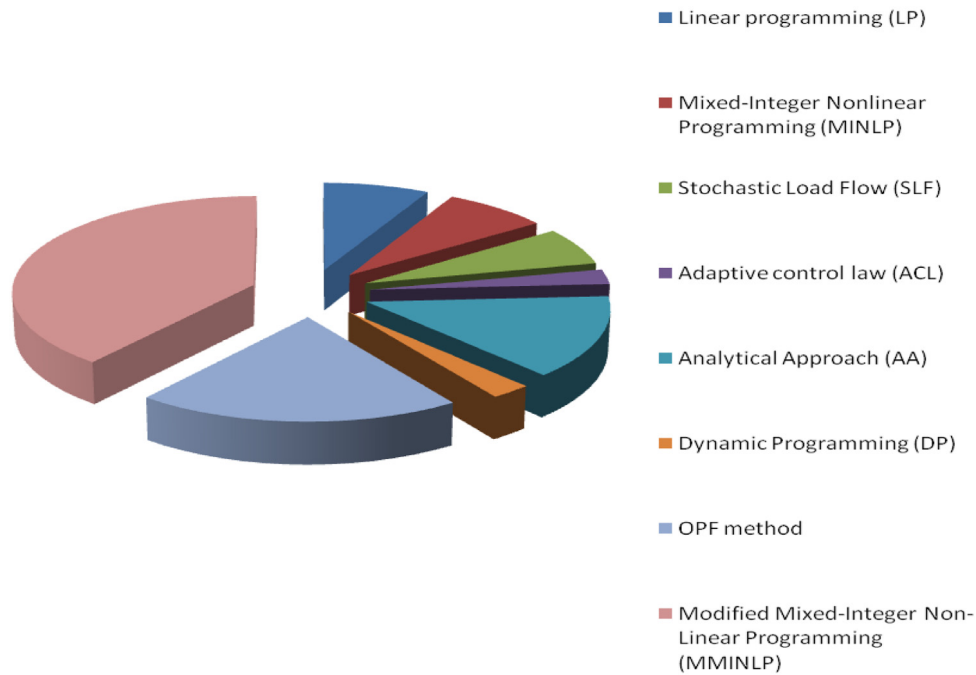


Fig. 2. Optimization techniques.

% Literatures reviewed from AI techniques viewpoint

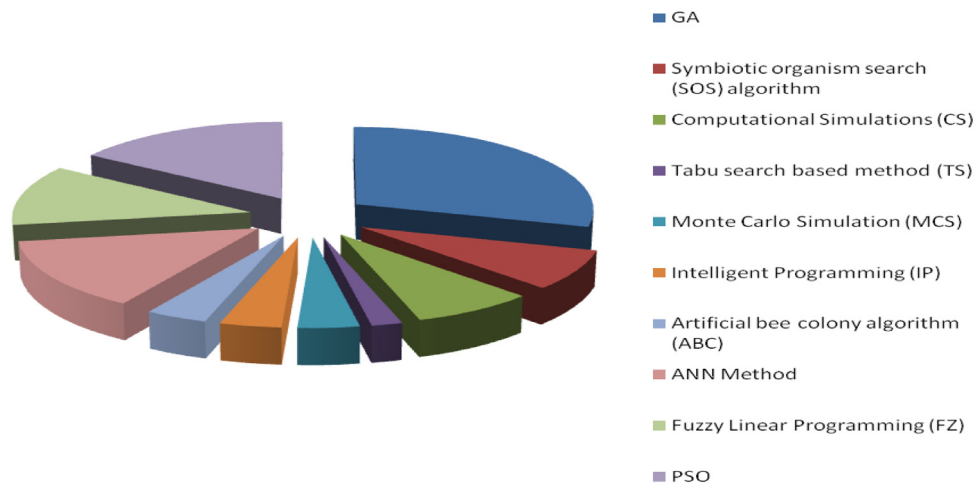


Fig. 3. Artificial intelligence computational techniques.

3.5. Current techniques

Table 11 and Fig. 5, shows the summary of this article from current techniques for enhancement of system performances by different FACTS controllers in power systems with static and realistic load models viewpoint.

Fig. 5, it is concluded that the EA, ACT, PM, HT, PP, GS, DC, WOA, GWO, MHA, SSO, GOA, ALO and SMO are 22.97%, 28.38%, 12.16%, 9.46%, 5.41%, 4.05%, 2.70%, 1.35%, 1.35%, 2.70%, 1.35%, 1.35%, 1.35% and 5.41% literatures are reviewed from current techniques viewpoint respectively.

3.6. Comparisons of all optimization techniques

Fig. 6, show the summary of this article from conventional, optimization, artificial intelligence, hybrid and current techniques for enhancement of system performances by different FACTS controllers in power systems with static and realistic load models, respectively (see Table 12).

Finally, it is concluded that, presently researchers and practitioners are used hybrid techniques (GA+PSO; GA+ANN+FZ;

% Literatures reviewed from hybrid technique viewpoint

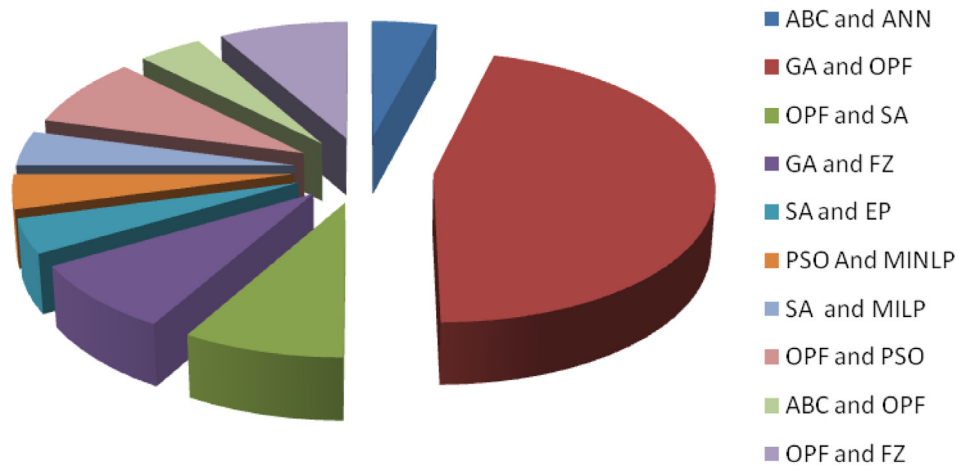


Fig. 4. Hybrid techniques.

% Literatures reviewed from current techniques viewpoint

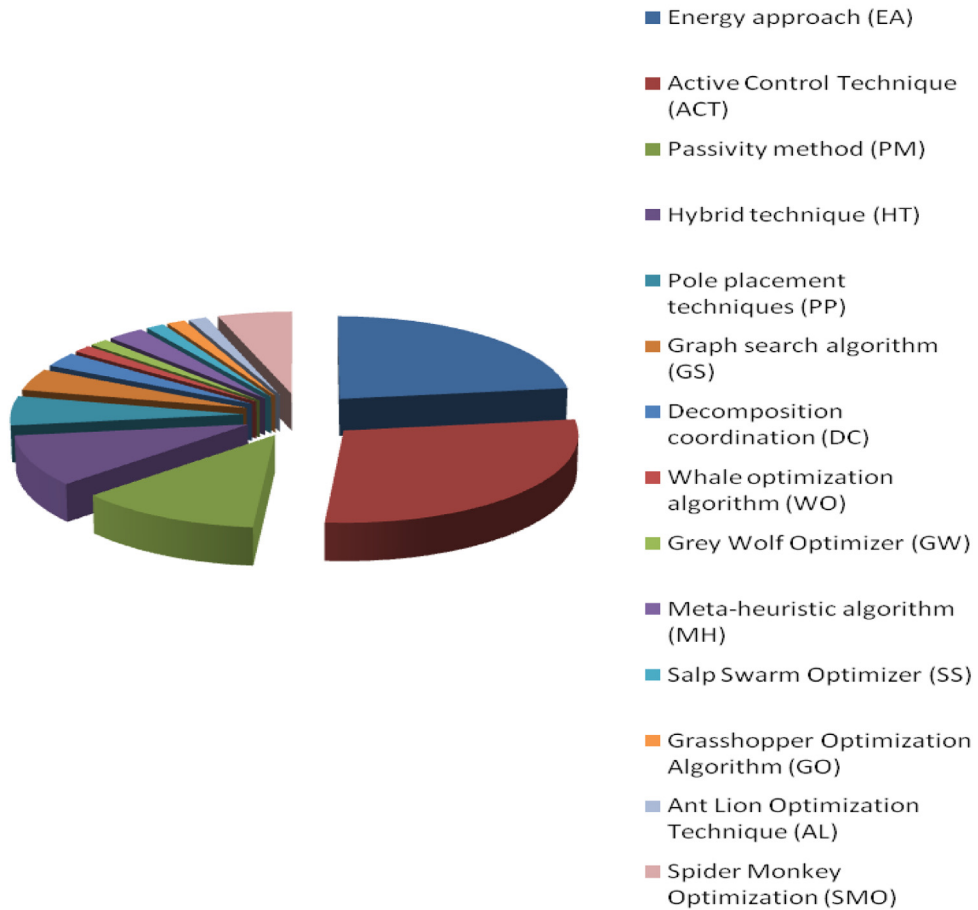


Fig. 5. Others techniques (Current techniques).

% Literatures reviewed from all optimization techniques viewpoints

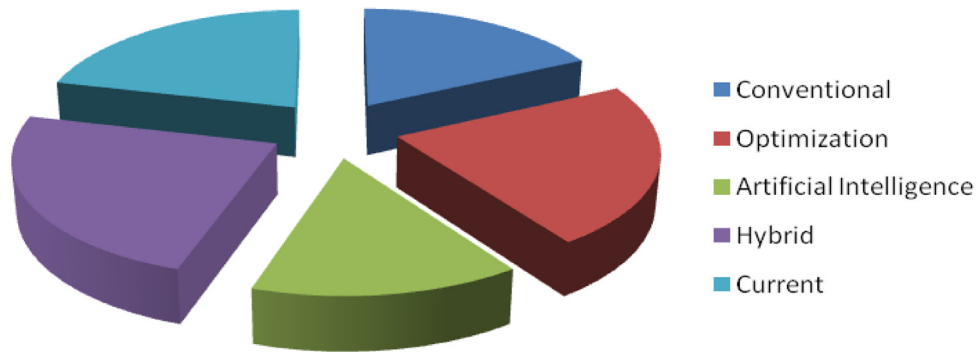


Fig. 6. Comparisons of all optimization techniques.

Table 10
Hybrid techniques.

Hybrid techniques	Literatures reviewed	% Literatures reviewed
ABC and ANN	1	4.17
GA and OPF	11	45.83
OPF and SA	2	8.33
GA and FZ	2	8.33
SA and EP	1	4.17
PSO And MINLP	1	4.17
SA and MILP	1	4.17
OPF and PSO	2	8.33
ABC and OPF	1	4.17
OPF and FZ	2	8.33

Table 11
Others techniques (current techniques)

Others techniques	Literatures reviewed	% Literatures reviewed
Energy approach (EA)	17	22.97
Active Control Technique (ACT)	21	28.38
Passivity method (PM)	9	12.16
Hybrid technique (HT)	7	9.46
Pole placement techniques (PP)	4	5.41
Graph search algorithm (GS)	3	4.05
Decomposition coordination (DC)	2	2.70
Whale optimization algorithm (WO)	1	1.35
Gray Wolf Optimizer (GW)	1	1.35
Meta-heuristic algorithm (MH)	2	2.70
Salp Swarm Optimizer (SS)	1	1.35
Grasshopper Optimization Algorithm (GO)	1	1.35
Ant Lion Optimization Technique (AL)	1	1.35
Spider Monkey Optimization (SMO)	4	5.41

Table 12
Comparisons of all optimization techniques.

Techniques	Literatures reviewed	% Literatures reviewed
Conventional	62	21.38
Optimization	79	27.24
Artificial Intelligence	51	17.59
Hybrid	24	28.62
Current	74	25.52

PSO+ANN; GA+MCS; GA+ABC; TS+MCS etc.) and current techniques (Grasshopper optimization techniques, Whale optimization techniques, Ant lion optimization techniques, Elephant heard

optimization techniques, Gray wolf optimization techniques, Gray swarm optimization techniques etc.) for enhancement of system performances.

4. Conclusions and future scopes of the survey article

The conclusions and future scopes of taxonomical survey article are presented in Sections 4.1–4.2, subsequently.

4.1. Conclusions

The following conclusions are made from this survey article as follows:-

- The enhancement of system performances such as loadability, real and reactive power losses, voltage profiles, power system stability, bandwidth of operations, flexibility of operations, available power transfer capacity, bandwidth of operations, power system oscillations, system power factors etc. by FACTS controllers in power systems with static and realistic load models.
- The power system reliability and security also enhanced by different types of FACTS controllers in power systems with static and realistic load models.
- The cost of electricity also reduced by different types of FACTS controllers in power systems.

4.2. Future scopes of survey article

The following future scopes of paper are as follows:-

- The practical systems are implemented with different types of FACTS controllers in multi-machines power systems with static and realistic load models.
- Multi-task objective also achieved by different types of FACTS controllers in multi-machines power systems with static and realistic load models.
- Environmental friendliness achieved by different types of FACTS Controllers in multi-machines power systems with static and realistic load models.

References

Abdel-Magid, Y.L., Abido, M.A., Al-Baiyat, S., Mantawy, A.H., 1999. Simultaneous stabilization of multi machine power systems via genetic algorithms. *IEEE Trans. Power Syst.* 14 (4), 1428–1439.

- Abdel-Magid, Y.L., Abido, M.A., Mantawy, A.H., 2000. Mantawy AH robust tuning of power system stabilizers in multi machine power systems. *IEEE Trans. Power Syst.* 15 (2), 735–740.
- Abhou Elaa, A., et al., 2010. Maximal optimal benefits of distributed generation using genetic algorithms. *Electr. Power Syst. Res.* 80, 869–877.
- Abido, M.A., 2002. Optimal design of power system stabilizers using PSO. *IEEE Trans. Energy Convers.* 17 (3), 406–413.
- Accha, E., et al., 2004. *FACTS Modelling and Simulation in Power Network*. John Wiley & Sons Ltd.
- Acchha, E., et al., 2000. Advanced SVC model for Newton–raphson load flow and Newton optimal power flow studies. *IEEE Trans. Power Syst.* 15 (1), 129–136.
- Adnan, M., Tariq, M., Zhou, Z., Vincent Poor, H., 2018. Load flow balancing and transient stability analysis in renewable integrated power grids. *Electr. Power Energy Syst.* 104, 744–771.
- Aghaei, J., Zarei, M., Asban, M., Ghavidel, S., Heidari, A., Agelidis, V.G., 2016. Determining potential stability enhancements of flexible ac transmission system devices using corrected transient energy function. *IET Gen. Trans. Distrib.* 10 (2), 470–476.
- Ahsae, M.G., Sadeh, J., 2011. A novel fault-location algorithm for long transmission lines compensated by series FACTS devices. *IEEE Trans. Power Del.* 26 (4), 2299–2308.
- Ajjarapu, V., Chrithy, C., 1992. The continuation power flow: A tool for steady state voltage stability analysis. *IEEE Trans. Power Syst.* 7 (1), 416–423.
- Ajjarapu, V., Crishty, C., 1992. The continuation power flow: A tool for steady state voltage stability analysis. *IEEE Trans. Power Syst.* 7 (1), 416–423.
- Alamhelu, S., et al., 2008. Novel optimal placement UPFC based on sensitivity analysis and evolutionary programming. *J. Eng. Appl. Sci.* 3 (1), 59–63.
- Alhasawi, Faisal B., Jovica, V.M., 2012. Techno-economic contribution of FACTS devices to the operation of power systems with high level of wind power integration. *IEEE Trans. Power Syst.* 27 (3), 1414–1421.
- Angquist, L., et al., 1993. Power oscillation damping using controlled reactive power compensation – A comparison between series and shunt approaches. *IEEE Trans. Power Syst.* 8 (2), 687–695.
- Ara, A.L., Kazemi, A., Niaki, S.A., 2012. Multi objective optimal location of FACTS shunt-series controllers for power system operation planning. *IEEE Trans. Power Deliv.* 27 (2), 481–490.
- Araby, E.E.E., Yorino, N., Saraki, H., 2002. A comprehensive approach of FACTS devices optimal allocation to mitigate voltage collapse In: *Proc2002, IEEE trans. and distrib. conf Exhibits*; 33 62–67.
- Ardhakhani, M.S., et al., 2016. Transfer capability improvement through market-based operation of series FACTS devices. *IEEE Trans. Power Syst.* 31 (5), 3702–3714.
- Azhbe, V., Ghabrijel, U., Povh, D., Milhalic, R., 2005. The energy function of a general multi machine system with a unified power flow controller. *IEEE Trans. Power Syst.* 20 (3), 1478–1485.
- Baek, Seung Mook, Nam, Suchul, Song, Jiyoung, Lee, Jaegul, Kim, Taekyun, Shin, Jeonghoon, 2013. Design of advanced voltage management system including manual operation mode via real-time digital simulator. *IEEE Trans. Ind. Appl.* 49 (4), 1817–1826.
- Bakar, Noorsakinah Abu, Desa, Mohd Khairunaz Mat, 2017. Optimal Placement of TCSC in Transmission Network using Sensitivity Based Method for Multi Objective Optimization IEEE Conf. on Energy Conv. (CENCON) 321–329.
- Bakhirtzis, A.G., Biskhas, P.N., Zhouma, C.E., Pethridish, V., 2002. Optimal power flow by enhanced genetic algorithm. *IEEE Trans. Power Syst.* 17 (2), 229–236.
- Bazanella, A.S., Shilva, A.S., 2001. Coordinated design of damping controllers for robustness of power systems stability. *Int. J. Electr. Power Energy Syst.* 23 (1), 69–79.
- Bedoya, D., Castro, C., de Silva, L., 2008. A method for computing minimum voltage stability margins of power systems. *IET Gen. Trans. Distrib.* 2 (5), 676–689.
- Behera, Tanmaya Kumar, Behera, Manoj Kumar, Nayak, Niranjan, 2018. Spider Monkey Based Improve P & O MPPT Controller for Photovoltaic Generation System, In: *Int. Conf. on Tech. for Smart-City Energy Security and Power (ICSESP-2018)*.
- Benabidh, R., Badhour, M., Abidho, M.A., 2009. Optimal location and setting of SVC and TCSC devices using non-dominated sorting particle swarm optimization. *Elect. Power Syst. Res.* 79 (12), 1668–1677.
- Blanco, G., Olsina, F., Garcés, F., Rehtanz, C., 2011. Real option valuation of FACTS investments based on the least square Monte Carlo method. *IEEE Trans. Power Syst.* 26 (3), 1389–1398.
- Cai, L.J., Erlich, I., 2006. Fuzzy coordination of FACTS controllers for damping power oscillations. *IEEE Trans. Power Syst.* 23–30.
- Cai, L.J., Erlich, I., Stamtsis, G., 2005. Optimal Choice and Allocation of FACTS Devices in Deregulated Electricity Market Using Genetic Algorithms In *Proc., IEEE Power Engg. Soc., General Meeting*, 201–207.
- Canizares, C.A., et al., 1996. Comparison of performance indices for detection of proximity of voltage collapse. *IEEE Trans. Power Syst.* 11 (3), 1441–1450.
- Canizares, C.A., et al., 1999. Analysis of SVC and TCSC controllers in voltage collapse. *IEEE Tran. Power Syst.* 14 (1), 158–165.
- Carpinelli, G., Caramia, Pierluigi, Russo, Angela, Varilone, Pietro, 2015. Voltage stability in unbalanced power systems: new complementarity constraints based approach. *IET Gener. Trans. Distrib.* 9 (14), 2014–2023.
- Carpinelli, G., Lauria, D., Varilone, P., 2006. Voltage stability analysis in unbalanced power systems by optimal power flow. *IEE Proc. Gen. Trans. Distrib.* 153 (3), 261–268.
- Chandra sekaran, K., Arul, K.J.A., Sahayasen thamil, L., Saravanan, M., 2009. A new method to incorporate FACTS devices in optimal power flow using particle swarm optimization. *J. Theor. Appl. Inf. Technol.* 14, 1–34.
- Chandrasekaran, K., Arul Jey Araj, K., Sahayasenthamil, L., Saravanan, M., 2005–2009. A new method to incorporate FACTS devices in optimal power flow using particle swarm optimization. *J. Theor. Appl. Inf. Technol.* 67–74.
- Chang, C.S., Huang, J.S., 1997a. Optimal SVC placement for voltage stability reinforcements. *Electr. Power Syst. Res.* 45 (3), 165–172.
- Chang, C.S., Huang, J.S., 1997b. Optimal SVC placement for voltage stability reinforcements. *Electr. Power Syst. Res.* 42, 165–172.
- Chang, B., Lee, B., Chow, J.H., 2009a. A novel operation strategy for shunt-type FACTS controllers in the KEPCO system. *IEEE Trans. Power Syst.* 24 (3), 1639–1640.
- Chang, B., Lee, Byongjun, Joe, H.C., 2009b. A novel operation strategies for shunt-type FACTS controllers in the KEPCO system. *IEEE Trans. Power Syst.* 24 (3), 1639–1640.
- Chatterji, D., et al., 2007. Transient stability assessment of power systems containing series and shunt compensators. *IEEE Tran. Power Sys.* 22 (3), 1210–1220.
- Chen, J., Lie, T.T., Vilathgamuwa, D.M., 2003. Enhancement of power system damping using VSC-based series-connected FACTS controller. *IEEE Proc.-Gen. Trans. Distrib.* 150 (3), 353–359.
- Chen, X., Pahalawaththa, N., Annakkage, U., Kumbe, C., 1995. Controlled series compensation for improving the stability of multi machine power systems. *IEEE Proc. Pt. C* 142, 361–366.
- Choudari, B., et al., 2004. Robust damping of multiple swing modes employing global stabilizing signals with a TCSC. *IEEE Trans. Power Syst.* 19 (1), 499–506.
- Chung, T.S., Li, Y.Z., 2001. A hybrid GA approaches for OPF with consideration of FACTS devices. *IEEE Power Eng. Rev.* 21 (2), 47–50.
- Chung, C.Y., Wang, K.W., Tse, C.T., Bian, X.Y., David, A.K., 2003. Probabilistic eigen value sensitivity analysis and PSS design in multi-machine power systems. *IEEE Trans. Power Syst.* 18 (4), 1439–1445.
- Ciofi, Carmine, Crupi, Felice, Pace, Calogero, 2002. A new method for high-sensitivity noise measurements. *IEEE Trans. Instrum. Meas.* 51 (4), 656–659.
- Conejo, A.J., Milano, F., Garcia-Bertrand, R., 2006. Congestion management ensuring voltage stability. *IEEE Trans. Power Syst.* 21 (1), 357–364.
- Crisan, Liu M., 1994. Voltage collapse prediction using an improved sensitivity approach. *Electr. Power Syst. Res.* 28 (3), 181–190.
- Cutsem, T.V., 1995. An approach to corrective control of voltage instability using simulation and sensitivity. *IEEE Trans. Power Syst.* 10 (2), 616–622.
- Daas, P.K., et al., 2000. Damping multimodal power system oscillation using hybrid fuzzy controller for series connected FACTS devices. *IEEE Trans. Power Syst.* 15 (4), 1360–1366.
- Daskh, P.K.S.M., Paanda, G., 2000. A radial basis function neural network controller for UPFC. *IEEE Trans. Power Sys.* 15 (4), 1293–1299.
- Deng, Zhuoming, Liu, Mingbo, Ouyang, Yifeng, Lin, Shunjiang, Xie, Min, 2018. Multi-objective mixed-integer dynamic optimization method applied to optimal allocation of dynamic VAR sources of power systems. *IEEE Trans. Power Syst.* 33 (2), 1683–1697.
- Dhas, P.K., et al., 2000. A radial basis function neural network controller for UPFC. *IEEE Trans. Power Syst.* 15 (4), 1293–1299.
- Dhong, Z., Wang, Y., Hill, D.J., Makharov, Y.V., 0000. A New Approach to Power Systems VAR Planning Aimed at Voltage Stability Enhancement with Feedback Control, In: *Proc. 1999, Electric Power Engineering Power Tech. Budapest '99*, pp. 33–39.
- Dillon, T.S., 1991. Artificial neural network applications to power systems and their relationship to symbolic methods. *Electr. Power Energy Syst.* 13 (2), 66–72.
- Edris, A., 2000. FACTS technology development: an update. *IEEE Power Eng. Rev.* 20 (3), 4–9.
- Etingov, Pavel, Oudalov, Alexandre, Voropai, Nikolai, Cherbaoui, Rachid, Germond, Alain, 2007. PSS Enhancement Using ANN Based Coordinated Emergency Control System, In: *Proc. of the IEEE Power Tech. 2007, Lausanne*, pp. 232–237.
- Faershang, M., et al., 2007. Placement of SVCs and selection of stabilizing signals in power systems. *IEEE Trans. Power Syst.* 22 (3), 1061–1071.
- Fang, X., Chow, J.H., Xia, J., Fardanesh, B., 2009. Sensitivity methods in the dispatch and siting of FACTS controllers. *IEEE Trans. Power Syst.* 24 (2), 713–720.
- Farsangi, M.M., Pour, N.H., Song, Y.H., Lee, K.Y., 2007. Placement of SVCs and selection of stabilizing signals in power systems. *IEEE Trans. Power Syst.* 22 (3), 1061–1071.

- Feurthe Eshquivel, C.R., Accha, E., 1997. A Newton-type algorithm for the control of power flow in electrical power networks. *IEEE Trans. Power Sys.* 12, 1474–1481.
- Gabrijel, U., et al., 2002. Direct methods for transient stability assessment in power systems comprising controllable series devices. *IEEE Trans. Power Syst.* 17 (4), 1116–1122.
- Gan, De, Thomas, R.J., Zimmerman, R.D., 2000. Stability-constrained optimal power flow. *IEEE Trans. Power Syst.* 15 (2).
- Gao, Fei, Bozhko, Serhiy, Costabeber, Alessandro, Patel, Chintan, Wheeler, Pat, Hill, Christopher, Asher, Greg, 2017. Comparative stability analysis of droop control approaches in voltage source converters-based DC micro grids. *IEEE Trans. Power Electron.* 32 (3), 2395–2415.
- Gao, B., Morison, G.K., Kund, P., 1992. Voltage stability evaluation using modal analysis. *IEEE Trans. Power Syst.* 7 (4), 1529–1542.
- George, Thomas, Youssef, Abdel Raheem, Ebeed, Mohamed, Kamel, Salah, 2018. Ant Lion Optimization Technique for Optimal Capacitor Placement Based on Total Cost and Power Loss Minimization, In: *Int. Conf. on Innovative Trends in Computer Engg. (ITCE)*, pp. 350–356.
- Gerbex, S., Charkai, R., Garmand, A.J., 2001. Optimal location of multi-type FACTS devices in a power system by means of genetic algorithms. *IEEE Trans. Power Syst.* 16 (3), 537–544.
- Gerbhex, S., Cherkhaoui, R., Garamond, A.J., 2001. Optimal location of multi-type FACTS devices in power system by means of genetic algorithm. *IEEE Trans. Power Syst.* 16 (3), 537–544.
- Ghaliana, F.D., Almeida, K., Toussaint, M., Griphin, J., Atanackovic, D., Ooi, B.T., MachGillis, D.T., 1996. Assessment and control of the impact of FACTS devices on power system performance. *IEEE Trans. Power Syst.* 11 (4), 1931–1936.
- Gharbex, Steephane, Chherkaou, Racid, Gormond, Alhein J., 2001. Optimal location of multi-type FACTS devices in a power system by means of genetic algorithms. *IEEE Trans. Power Syst.* 16 (3), 537–544.
- Gholipour, E.S.S., 2005. Improving of transient stability of power systems using UPFC. *IEEE Trans. Power Deliv.* 20 (2), 1677–1682.
- Ghyugi, L., Shen, K.K., Schauder, C.D., 1999. The interline power flow controller concept: a new approach to power flow management in transmission systems. *IEEE Trans. Power Deliv.* 14 (3), 1115–1123.
- Ghyugyi, L., et al., 1999. The interline power flow controller concept: a new approach to power flow management in transmission line system. *IEEE Trans. Power Deliv.* 14 (3), 1115–1123.
- Gibbard, M.J., Vowles, D.J.P.P., 2000. Interactions between and effectiveness of power systems stabilizers and FACTS controllers in multi-machine systems. *IEEE Trans. Power Syst.* 15 (2), 748–755.
- Gitizadeh, M.M.K., 2009. A novel approach for optimum allocation of FACTS devices using multi-objective function. *Energy Convers. Manage.* 50 (3), 682–690.
- Goksu, Omer, Teodorescu, Remus, Bak, Claus Leth, Iov, Florin, Kjaer, Philip Carne, 2014. Instability of wind turbine converters during current injection to low voltage grid faults and PLL frequency based stability solution. *IEEE Trans. Power Syst.* 29 (4), 1683–1691.
- Golipour, E., Shadate, S., 2005. Improving transient stability of power systems using UPFC. *IEEE Trans. Power Deliv.* 20 (2), 1677–1682.
- Gonzalez, J., et al., 2010. Stability modelling and comparative study of series vectorial compensators. *IEEE Trans. Power Del.* 25 (2), 1093–1103.
- Gubina, F., Strmcnik, B., 1995. Voltage collapse proximity index determination using voltage phasor approach. *IEEE Trans. Power Syst.* 10 (2), 788–793.
- Gui, Yonghao, Kim, Wonhee, Chung, Chung Choo, 2016. Passivity-based control with nonlinear damping for type 2 STATCOM systems. *IEEE Trans. Power Syst.* 31 (4), 2824–2833.
- Guo, Y., Gao, H., Wu, Qiuwei, Ostergaard, Jacob, Dachuan, Shahidepour, M., 2018a. Distributed coordinated active and reactive power control of wind farms based on model predictive control. *Electr. Power Energy Syst.* 104, 78–88.
- Guo, C., Jiang, Wen, Zhao, Chengyong, 2018b. Small-signal instability and supplementary coordinated damping-control of LCC-HVDC system with STATCOM under weak AC grid conditions. *Electr. Power Energy Syst.* 104, 246–254.
- Hajagos, L., Danai, B., 1998. Laboratory measurements and models of modern loads and their effect on voltage stability studies. *IEEE Trans. Power Syst.* 13 (2), 584–592.
- Hamed, H.D., Masoud, M.S., Hossein, A.A., Gevork, G., Mehdi, G., 2013. A new method based on sensitivity analysis to optimize the placement of SSSCs. *Turk. J. Electr. Eng. Comput. Sci.* 21, 1956–1971.
- Hammad, A.E., Al Sadek, M.Z., 1989. Prevention of transient voltage instabilities due to induction motor loads by static var compensators. *IEEE Power Eng. Rev.* 9 (8).
- Hamon, Camille, Perninge, Magnus, Soder, Lennart, 2013. A stochastic optimal power flow problem with stability constraints, Part I: Approximating the stability boundary. *IEEE Trans. Power Syst.* 28 (2), 1839–1848.
- Hamour, Hanan, Kamel, Salah, mawgoud, Hussein Abdel, Korashy, Ahmed, Jurado, Francisco, 2018. Distribution Network Reconfiguration Using Grasshopper Optimization Algorithm for Power Loss Minimization, In: *Int. Conf. on Smart Energy Systems and Tech. (SEST)*, pp. 1–5.
- Hazhra, J., et al., 2007. Congestion management using multi objective particle swarm optimization. *IEEE Trans. Power Syst.* 22 (4), 1726–1734.
- Hazrati, Garima, Sharma, Harish, Sharma, Nirmala, Adaptive Step-size based Spider Monkey Optimization Adaptive Step-size based Spider Monkey Optimization, In: *Int. Conf. on Power Electronics, Intelligent Control and Energy Systems (ICPEICES-2016)*, pp. 1–5.
- Hoque, M., 2004. Improvement of first swing stability limit by utilizing full benefit of shunt FACTS devices. *IEEE Tran. Power Syst.* 19 (4), 1894–1902.
- Hoque, M., 2008. Evaluation of first swing stability of a large power system with various FACTS devices. *IEEE Tran. Power Syst.* 23 (3), 1144–1151.
- Hossain, M.J., Pota, Hemanshu R., Apel Mahmud, M.d., Rodrigo, A.R., 2012. Investigation of the impacts of large-scale wind power penetration on the angle and voltage stability of power systems. *IEEE Syst. J.* 6 (1), 76–84.
- Hridya, K.R., Mini, V., Visakhan, R., Kurian, Asha Anu, 2015a. Analysis of Voltage Stability Enhancement of a Grid and Loss Reduction Using Series FACTS Controllers, *IEEE Int. Conf. on Power, Instru. Control and Computing (PICC)*, 1–5.
- Hridya, K.R., Mini, V., Visakhan, R., Kurian, Asha Anu, 2015b. Analysis of Voltage Stability Enhancement of a Grid and Loss Reduction Using Series FACTS Controllers *Int. Conf. on Power, Instru. Control and Computing (PICC)*.
- Hu, Pengfei, Guerrer, Josep M., He, Zhengxu, 2018. Design and analysis of a transformerless STATCOM based on hybrid cascaded multilevel converter. *Electr. Power Energy Syst.* 104, 78–88.
- Hu, Fengkai, Sun, Kai, Rosso, Alberto Del, Farantatos, Evangelos, Bhatt, Navin, 2016. Measurement-based real-time voltage stability monitoring for load areas. *IEEE Trans. Power Syst.* 31 (4), 2787–2798.
- Hua, Pengfei, Guerrerob, Josep M., He, Zhengxu, 2019. Design and analysis of a transformer less STATCOM based on hybrid cascaded multilevel converter. *Electr. Power Energy Syst.* 104, 694–704.
- Huang, J., Jiang, Z., Negnevitsky, M., 2012. Optimal SVC Placement for Voltage Stability Reinforcement of Power Systems with Most Critical and N-1 Security Criteria, *IEEE Energycon. Conf. & Exh.*
- Huang, Z., Ni, Y., Shen, C.M., Wu, F.F., Shousun, C., Baolin, Z., 2000. Application of unified power flow controller in interconnected power systems modeling, interface, control strategy, and case study. *IEEE Trans. Power Syst.* 15 (2), 817–824.
- Ippolito, L., Cortiglia, Antonio La, Petrocchi, Michele, 2006. Optimal allocation of FACTS devices by using multi-objective optimal power flow and genetic algorithms. *Int. J. Emerg. Electric. Power Sys.* 7 (2).
- Jadidbonab, M., et al., 2019. Stochastic assessment, enhancement of voltage stability in multi carrier energy systems considering wind power. *Int. J. Electr. Power Energy Syst.* 106, 572–584.
- Jeevarathinam, B., 2006. Genetic algorithm and Fuzzy logic based optimal location of FACTS device in a power system network. *Int. J. Emerg. Electric. Power Syst.* 5 (2).
- Jiang, Xia, Chow, Joe H., Edris, A.A., Fardanesh, B.E.U., 2010. Transfer path stability enhancement by voltage-sourced converter-based FACTS controllers. *IEEE Trans. Power Deliv.* 25 (2), 1019–1025.
- Kalyan Kumar, B., et al., 2007. Placement of FACTS controllers using modal controllability indices to damp out power system oscillations. *IET Gen. Trans. Distrib.* 1 (2), 209–217.
- Kamarposhti, M.A., Alinezhad, M., Lesani, H., Talebi, N., 2008. Comparison of SVC, STATCOM, TCSC, and UPFC controllers for static voltage stability evaluated by continuation power flow method, *IEEE Canada Electric Power Conference* pp. 1–8.
- Kamel, S., Jurado, F., Lopes, J.P., 2015. Comparison of various UPFC models for power flow control. *Int. J. Electr. Power Syst. Res.* 121, 243–251.
- Kanan, S., et al., 2004. Real and reactive power coordination for a UPFC. *IEEE Trans. Power Syst.* 19 (3).
- Kannan, S., Mary, R.S.S., Subbaraj, P., Pandhay, N.P., 2004. Application of PSO technique and its variants to generation expansion planning problem. *Electric Power Sys. Res.* 70, 203–210.
- Kaur, Avinash, Sharma, Harish, Sharma, Nirmala, Disruption operator based Spider Monkey Optimization Algorithm, In: *Int. Conf. on Computing, Communication and Automation (ICCCA2017)*, pp. 216–225.
- Kejani, Mohsen Basiri, Gholipour, Eskandar, 2017. Holomorphic embedding load-flow modeling of thyristor-based FACTS controllers. *IEEE Trans. Power Syst.* 32 (6), 4871–4879.
- Kesshel, P., Ghlavitsch, H., 1986. Estimating the voltage stability of a power system. *IEEE Trans. Power Del.* 1 (3), 346–354.
- Khalesi, N., Rezaei, N., Haghifam, M.R.D.G., 2011. Allocation with application of dynamic programming for loss reduction and reliability improvement. *Int. J. Electr. Power Energy Syst.* 33 (2), 288–295.
- Khederzadeh, M., Ghorbani, A., 2012a. Impact of VSC-based multilines facts controllers on distance protection of transmission lines. *IEEE Trans. Power Del.* 27 (1), 32–39.
- Khederzadeh, Mojtaba, Ghorbani, Amir, 2012b. Impact of VSC-based multilines FACTS controllers on distance protection of transmission lines. *IEEE Trans. Power Del.* 27 (1), 32–39.
- Khederzadeh, M., Sidhu, T.S., 2006. Impact of TCSC on the protection of transmission lines. *IEEE Trans. Power Del.* 21 (1), 80–87.

- Kheib, A., et al., 1995. Application of artificial neural networks in voltage stability assessment. *IEEE Trans. Power Syst.* 10 (4), 1890–1895.
- Kimkhratug, P., 2012. Application of lyapunov theory and fuzzy logic to control shunt FACTS devices for enhancing transient stability in multi machine system. *J. Electr. Eng. Technol.* 7 (5), 672–680.
- Kinjo, T., Senjyu, T., Urasaki, N.H.F., 2006. Output levelling of renewable energy by electric double-layer capacitor applied for energy storage system. *IEEE Trans. Energy Convers.* 21 (1).
- Ko, Chia Nan, Chang, Ying-Pin, Wu, Chia Ju, 2009. A PSO method with nonlinear time-varying evolution for optimal design of harmonic filters. *IEEE Trans. Power Syst.* 24 (1), 437–444.
- Kobayashi, K., Goto, M., Wu, K., Yokomizu, Y., Matsumura, T., 2003. PSS improvement by energy storage type STATCOM. *IEEE Power Soc. Meet.* 0–7803–7967–5.
- Krishnan, Vignesh Venkata Gopala, Srivastava, Suresh Chandra, Chakrabarti, Saikat, 2018. A robust decentralized wide area damping controller for wind generators and FACTS controllers considering load model uncertainties. *IEEE Trans. Smart Grid* 9 (1), 360–372.
- Kumar, N., Dhava, M.P., 1995. Application of static VAR system auxiliary controllers to improve the transient performance of series compensated line transmission lines. *Electr. Power Syst. Res.* 34, 75–83.
- Kumar, B.K., Singh, S.N., Srivastava, S.C., 2007a. Placement of FACTS controllers using modal controllability indices to damp out power system oscillations. *IET Gen. Trans. Distrib.* 1 (2), 209–217.
- Kumar, B.K., et al., 2007b. Placement of FACTS controller using modal controllability indices to dampout power system oscillations. *Proc. Inst. Eng. Tech. Gen. Trans. Distr.* 1 (2), 252–260.
- Kumkhratuge, P., et al., 2003. Versatile model of a unified power flow controller in a simple power system. *Proc. Inst. Electr. Eng. Gen. Trans. Distrib.* 150 (2), 155–1161.
- Kumkhratuge, P., et al., 2003. Versatile model of a unified power flow controller in a simple power system. *IEEE Proc. Gen. Trans. Distrib.* 150 (2), 155–161.
- Kundhur, P., et al., 2004. Definition and classification of power system stability. *IEEE Trans. Power Syst.* 19 (2), 1387–1401.
- Kundur, P., Morison, G., 1997. A review of definitions and classification of stability problems in today's power systems, In: *Proc. IEEE PES Winter Meeting, Panel Session on Stability Terms and Definitions*, New York, USA.
- Kuyu, Yigit Cagatay, Vatansver, Fahri, 2018. Real Loss Minimization in Power Systems via Recent Optimization Techniques, In: *Int. Symposium on Multidisciplinary Studies and Innovative Techno. (ISMSIT)*, pp. 1–4.
- Ladhumaor, Dilip, et al., 2017. Optimal power flow with Shunt flexible AC transmission system (FACTS) device using Grey Wolf Optimizer, In: *Int. Conf. on adv. in Electrical, Electronics, Inf. Comm. and Bio Informatics (AEEICB17)*, pp. 387–391.
- Ladhumaor, Dilip P., et al., 2017. Optimal power flow problems solution with SVC using meta-heuristic algorithm, In: *Int. Conf. on Advances in Electrical, Electronics, Inf. Comm. and Bio-Inf. (AEEICB)*, pp. 283–288.
- Larshen, E.V., Sanchezh Ghasca, J., Chaow, J.H., 1995. Concepts for design of FACTS controllers to damp power swings. *IEEE Trans. Power Syst.* 10 (2), 948–956.
- Lashkar, A.A., Kazemi, A., Niaki, S.A.N., 2012. Multi objective optimal location of FACTS shunt-series controllers for power system operation planning. *IEEE Trans. Power Deliv.* 27 (2), 481–490.
- Leiu, G., et al., 2000. Design and application of coordinated multiple FACTS controllers. *IEEE Proc. Gen. Trans. Distrib.* 147 (2), 112–120.
- Lhu, Y., Abhour, A., 2002. Static security enhancement via optimal utilization of thyristor-controlled series capacitor. *IEEE Trans. Power Syst.* 17 (2), 324–329.
- Li, Can, Deng, J., Zhang, X.P., 2017. Coordinated design and application of robust damping controllers for shunt FACTS devices to enhance small-signal stability of large-scale power systems. *CSEE J. Power Energy Syst.* 3 (4), 399–407.
- Li, B.H., Li, K.Y., 1993. Dynamic and Static voltage stability enhancement of power systems. *IEEE Trans. Power Syst.* 8, 231–238.
- Li, Yong, Rehtanz, Cristian, Ruberg, Sven, Luo, Longfu, Cao, Yijia, 2012a. Wide-area robust coordination approach of HVDC and FACTS controllers for damping multiple inter area oscillations. *IEEE Trans. Power Deliv.* 27 (3), 1096–1105.
- Li, Yong, Rehtanz, Christian, Ruberg, S., Lhuo, L., Chao, Yijia, 2012b. Assessment and choice of input signals for multiple HVDC and FACTS wide-area damping controllers. *IEEE Trans. Power Syst.* 27 (4), 1969–1977.
- Lie, T.T., Deng, W., 1997a. Optimal flexible ac transmission system (FACTS) devices allocation. *Electr. Power Energy Syst.* 19 (2), 125–134.
- Lie, Tjing T., Deng, Wanhong, 1997b. Optimal flexible AC transmission systems (FACTS) devices allocation. *Electr. Power Energy Syst.* 19 (2), 125–134.
- Lima, Flavio G.M., Galiana, Francisco D., Kockar, Ivana, Munoz, Jorge, 2003. Phase shifter placement in large scale systems via mixed integer linear programming. *IEEE Trans. Power Syst.* 18 (3), 1029–1034.
- Limchon, S., et al., 1998. Fuzzy logic based unified power flow controllers for transient stability improvement. *IEE Proc. Gen. Trans. Distrib.* 145 (3), 225–232.
- Limingcaron, S., et al., 1998. Effects of unified power flow controllers on transient stability. *Proc. Inst. Electr. Eng. Gen. Trans. Distrib.* 145 (2), 182–188.
- Limingcharoen, S., Annakkage, U.D., Pahalwatha, N.C., 1998. Effects of unified power flow controllers on transient stability. *IEEE Proc. Gen. Trans. Distrib.* 145 (2), 182–188.
- Liu, Shu, Messina, A.R., Vithal, Vijay, 2006. A normal form analysis approach to siting power system stabilizers (PSS) and assessing power system nonlinear behaviour. *IEEE Trans. Power Syst.* 21 (4).
- Lof, P.A., Anderson, G., Hill, D.J., 1993. Voltage stability indices of stressed power system. *IEEE Trans. Power Syst.* 8 (1), 326–335.
- M. M. Farsaang, Y.H.K.Y., 2004. Choice of FACTS device control inputs for damping inter area oscillation. *IEEE Trans. Power Syst.* 19 (2), 1135–1142.
- Madhtharad, C., et al., 2005. An optimal measurement placement method for power system harmonic state estimation. *IEEE Trans. Power Del.* 20 (2), 1514–1521.
- Mahdad, B., Bouktir, T., Srairi, K., Benbouzid, M.E.L., 2009. Optimal power flow with discontinuous fuel cost functions using decomposed GA coordinated with shunt FACTS. *J. Electr. Eng. Technol. KIEE* 4 (4), 457–466.
- Mancilla David, F., Venkataramanan, G., 2000. A pulse width modulated AC link unified power flow controller, In: *IEEE Power Engineering Society General Meeting, Vol. 2, San Francisco, CA*, pp. 1314–1321.
- Manganuril, Yogasree, Choudekar, Pallavi, Abhishek, Asija, Divya, Ruchira, 2016. Optimal Location of TCSC using Sensitivity and Stability Indices for Reduction in Losses and Improving the Voltage Profile. *IEEE Conf. on Power Electronics, Intelligent Control and Energy Systems (ICPEICES-2016)* 321–329.
- Manshour, Y., Xhu, W., Alvaradho, F., Rinzhin, C., 1994. SVC placement using critical modes of voltage instability. *IEEE Trans. Power Syst.* 9 (2), 757–763.
- Marthins, N., Lheema, L.T.G., 1990. Determination of suitable locations for power system stabilizers and static VAR compensators for damping electromechanical oscillations in large scale power systems. *IEEE Trans. Power Syst.* 5 (4), 1455–1469.
- Mehouachi, Ines, Abbes, Mohamed, Chebbi, Souad, 2019. Design of a high power D-STATCOM based on the isolated dual-converter topology. *Int. J. Electr. Power Energy Syst.* 106, 401–410.
- Mehraeen, S., Jagannathan, S., Crow, M.L., 2010. Novel dynamic representation and control of power systems with FACTS devices. *IEEE Trans. Power Syst.* 25 (3), 1542–1554.
- Mihilic, R., Zunkho, P., Phovh, D., 1996. Improvement of transient stability using unified power flow controller. *IEEE Trans. Power Deliv.* 11 (1), 485–492.
- Milhalic, R., Zhunko, P., 1996. Improvement of transient stability using unified power flow controller. *IEEE Trans. Power Del.* 1 (1), 485–492.
- Mishra, S., Dash, P.K., Panda, G., 2000. TS-fuzzy controller for UPFC in a multi-machine system. *IEE Proc. Gen. Trans. Distrib.* 147 (1), 15–22.
- Mithulantan, N., Canizores, C., Roevhe, J., Roggers, G., 2003. Comparison of pss, svc, and STATCOM for damping power system oscillations. *IEEE Trans. Power Syst.* 18 (2).
- Mohamad Idris, R., Khairuddin, A., Mustafa, M.W., 2010. Optimal allocation of FACTS devices in deregulated electricity market using bees algorithm. *Wseas Trans. Power Syst.* 5 (2).
- Mohsen, G., Mohsen, S.P., Mohammad, M., 2013. A new method for SVC placement considering FSS limit and SVC investment cost. *Int. J. Electr. Power Energy Syst.* 53, 900–908.
- Monod, S.W., Mohan, V., 2010. A STATCOM-control scheme for grid connected wind energy system for PQ improvement. *IEEE Syst. J.* 4 (3), 346–352.
- Mori, H., Goto, Y., 2000. Parallel Tabu Search Based Method for Determining Optimal Allocation of FACTS in Power Systems, In: *Proc. Power Conf. on Power System Technology*, pp. 1077–1082.
- Morioka, Y., Kato, M., Mishima, Y.Y.N., 1999a. Implementation of unified power flow controller and verification for transmission capability improvement. *IEEE Trans. Power Syst.* 14 (2), 575–581.
- Morioka, Y., Mishima, Y., Nakachhi, Y., 1999b. Implementation of unified power flow controller and verification of transmission capability improvement. *IEEE Trans. Power Syst.* 14, 575–581.
- Morris, Shtella, Dash, P., Bashu, K.P., 2003. A fuzzy variable structure controller for STATCOM. *Electr. Power Syst. Res.* 65 (1), 23–34.
- Mozhgan, B., 2012. Using neural network to control STATCOM for improving transient stability. *J. Artif. Intell. Electr. Eng.* 1 (1), 26–31.
- Mustafa, Mohd Wazir, Chiew, Wong Yan, 2008. Optimal placement of static VAR compensator using genetic algorithms. *Elektrika* 10 (1), 26–31.
- Muzzammel, Raheel, Ahsan, Muhammad, Ahmad, Waqas, 2015. Non-linear analytic approaches of power flow analysis and voltage profile improvement. *Power Gen. Syst. Renew. Energy Tech. (PGSRET)* 1–7.
- Nam, H.K., Kim, Y.K., Shim, K.S.K.Y.L., 2000. A new eigen-sensitivity theory of augmented matrix and its applications to power system stability analysis. *IEEE Trans. Power Syst.* 15 (1), 363–369.
- Naoto, Y., Araby, E.E.E., Hiroshi, S., Shigemi, H., 2003. A new formulation for FACTS allocation for security enhancement against voltage collapse. *IEEE Trans. Power Syst.* 18 (1), 54–65.
- Nar, K.S., et al., 1990. Identification and control of dynamical systems using neural networks. *IEEE Trans. Neural Netw.* 1 (1), 4–27.

- Nayak, Niranjana, Mahali, MitaliS, Majumder, Irani, Jena, RanjanK, Dynamic Stability Improvement of VSC-HVDC Connected Multi machine Power System by Spider Monkey optimization Based PI controller, In: *Int. Conf. on Electrical, Electronics and Optimization Techniques (ICEEOT) – 2016*, pp. 152–157.
- Nguyen, T.T., et al., 2008. Neural networks for adaptive control coordination of PSSs and FACTS devices in multi machine power system. *IET Gen. Trans. Distrib.* 2 (3), 355–372.
- Niaki, A.N., Irhivani, M.R., 1996. Steady-state and dynamic models of unified power flow controller (UPFC) for power system studies. *IEEE Trans. Power Syst.* 11 (4), 1937–1943.
- Niaki, A., Irhivani, M.R., 1996. Steady-state and dynamic models of unified power flow controller (UPFC) for power system studies. *IEEE Trans. Power Syst.* 11 (4), 1937–1943.
- Niknam, T., Narimani, M.R., Aghaei, J., Azizipناه, A.R., 2012. Improved PSO for multi-objective OPF considering the cost, loss, emission and voltage stability index. *IET Gen. Trans. Distrib.* 6 (6), 515–527.
- Nikoobakht, Ahmad, Aghaei, Jamshid, Parvania, Masood, Ardakani, Mostafa Sahraei, 2018. Contribution of FACTS devices in power systems security using MILP-based OPF. *IET Gen. Trans. Distrib.* 12 (15), 3744–3755.
- Nojavan, Morteza, Seyedi, Heresh, Ivatloo, Behnam Mohammadi, 2018. Voltage stability margin improvement using hybrid non-linear programming and modified binary particle swarm optimization algorithm considering optimal transmission line switching. *IET Gen. Trans. Distrib.* 12 (4), 815–823.
- Noruzhian, M., Anghquist, L., Gandhari, M., Andarsson, G., 1997. Use of UPFC for optimal power flow control. *IEEE Trans. Power Deliv.* 12 (4), 1629–1634.
- Noruzian, M., et al., 1997. Improving power system dynamics by series connected FACTS devices. *IEEE Trans. Power Deliv.* 12 (4), 1635–1641.
- Noruzian, M., et al., 1999. A robust control strategy for shunt and series reactive compensators to damp electromechanical oscillations. *IEEE Trans. Power Del.* 16 (4), 812–817.
- Nurzman, M., Andherson, G., Thomshovic, K., 1996. Robust, near time-optimal control of power system oscillations with fuzzy logic. *IEEE Trans. Power Del.* 11 (1), 393–400.
- Okamoto, H., Kurita, A.Y.S., 1995. A method for identification of effective locations of variable impedance apparatus on enhancement of steady-state stability in large scale power systems. *IEEE Trans. Power Syst.* 10 (3), 1401–1407.
- Olivheira, S.M., 1994. Synchronising and damping torque coefficients and power system steady-state stability as affected by static VAR compensators. *IEEE Trans. Power Syst.* 9 (1), 109–119.
- Ooi, B., Kazerani, M., Marceau, R., Wolanski, Z., Galiana, F., McGill's, D., Joos, G., 1997. Mid-point siting of FACTS devices in transmission lines. *IEEE Trans. Power Deliv.* 12 (5), 1717–1722.
- Orfano Gianni, T., Bacher, R., 2003. Steady-state optimization in power systems with series FACTS devices. *IEEE Trans. Power Syst.* 18 (1), 19–26.
- Orfanogianni, Tina, Bacher, Rainer, 2003. Steady-state optimization in power systems with series FACTS devices. *IEEE Trans. Power Syst.* 18 (1), 19–26.
- Padhiyaar, K.R., et al., 1998. Control design and simulation of unified power flow controller. *IEEE Trans. Power Deliv.* 13 (4), 1348–1354.
- Padhy, N.P., Abdel, M.M.A., 2004. Power flow control and solutions with multiple and multi-type FACTS devices. *Electr. Power Syst. Res.* 23 (3), 20–35.
- Pal, B.C., 2002. Robust damping of inter area oscillations with unified power flow controller. *IEEE Proc. Gen. Trans. Distrib.* 149 (6), 733–738.
- Panda, S., Ardil, C., 2008. Robust coordinated design of multiple power system stabilizers using PSO technique. *Int. J. Electr. Electron. Eng.* 1 (1), 23–45.
- Panda, Sidhartha, Ramnarayan, N.P., 2006. Improving power system transient stability with an off-centre location of shunt facts devices. *J. Electr. Eng.* 57 (6), 365–368.
- Pandey, Rajendra K., Gupta, Deepak Kumar, 2018. Integrated multi-stage LQR power oscillation damping FACTS controller. *CSEE J. Power Energy Syst.* 4 (1), 83–92.
- Pandha, S., Ardhil, C., 2007. Robust coordinated design of multiple power system stabilizers using particle swarm optimization technique. *Int. J. Electr. Electron. Eng.* 1 (1), 119–126.
- Paphic, I., Zhunko, P., Povh, D., Wheinhold, W., 1997. Basic control of unified power flow controller. *IEEE Trans. Power Syst.* 12 (4), 1734–1739.
- Paramasivam, M., Salloum, A., Ajarapu, V., et al., 2013. Dynamic optimization based reactive power planning to mitigate slow voltage recovery and short term voltage instability. *IEEE Trans. Power Syst.* 28 (4), 3865–3873.
- Park, Ji Ho, Baek, Young Sik, 2012. Coordination control of voltage between STATCOM and reactive power compensation devices in steady-state. *J. Electr. Eng. Technol.* 7 (5), 689–697.
- Parker, C.J., Morrison, I.F., Sutanto, D., 1996. Application of an optimization method for determining there active margin from voltage collapse in reactive power planning. *IEEE Trans. Power Syst.* 1473–1481.
- Perez, Ambriz, et al., 2006. TCSC-Firing angle model for optimal power flow solutions using newton's method. *Int. J. Electr. Power Energy Syst.* 28 (2), 77–85.
- Perkin, B.K., Ira, M.R., 1997. Dynamic modelling of a TCSC with application to SSR analysis. *IEEE Trans. Power Deliv.* 12 (4), 1619–1625.
- Phalliate, L.A., et al., 1997. Determination of needed FACTS controllers that increases asset utilization of power systems. *IEEE Trans. Power Del.* 12 (1), 364–371.
- Pillotto, L.A., et al., 1997. Determination of needed FACTS controllers that increase asset utilization of power system. *IEEE Trans. Power Deliv.* 12 (1), 364–371.
- Pilotto, L.A.S., Ping, W.W., Carvalho, A.R., F.Long, W., Alvarado, F.L., Demarco, C.L., Edris, A., 1997a. Coordinated design of FACTS controllers to enhance power system dynamic performance. In: *Int. Coll. on HVDC and FACTS*. Johannesburg.
- Pilotto, L., Ping, W., Carvalho, A., Wey, A., Long, W., Alvarado, F., Edris, A., 1997b. Determination of needed FACTS controllers that increase asset utilization of power systems. *IEEE Trans. Power Deliv.* 12 (1), 364–371.
- Pilotto, L.A.S., Ping, W.W., Carvalho, A.R., Wey, A., Long, W.F., Alvarado, F.L., Edris, A., 1997c. Determination of needed FACTS controllers that increases asset utilization of power system. *IEEE Power Eng. Rev.* 17 (1), 58–59.
- Pilotto, L.A.S., et al., 1997. Determination of needed FACTS controllers that increase asset utilization of power systems. *IEEE Trans. Power Del.* 12 (1), 234–243.
- Potamianakis, E.G., Vournas, C.D., 2006. Short-term voltage instability: effects on synchronous and induction machines. *IEEE Trans. Power Syst.* 21 (2), 791–798.
- Priti, V., Murlidaran, S., Rajshekhar, S., 2011. Application of Genetic Algorithm to Power System Voltage Stability Enhancement Using Facts Devices, In: *Int. Conf. on recent advance, in Electrical, Electronics and Control Engg*, pp. 333–338.
- Qader, M., 2015. Design, simulation of a different innovation controller-based UPFC for the enhancement of power quality. *Energy* 89, 576–592.
- Rahimzadeh, Sajad, Bina, Mohammad Tavakoli, 2011. Looking for optimal number and placement of FACTS devices to manage the transmission congestion. *Energy Convers. Manage.* 52, 437–446.
- Rashidi, M.R.A., Hawary, M.E.E., 2009. A survey of particle swarm optimization applications in electric power systems. *IEEE Trans. Evol. Comput.* 13 (4), 913–918.
- Reis, C., Maciel Barbosa, F.P., 2006. A Comparison of Voltage Stability Indices, In: *IEEE MELECON (Spain)*, pp. 1007–1010.
- Renzh, B., et al., 1999. AEP unified power flow controller performance. *IEEE Trans. Power Del.* 14 (4), 1374–1381.
- Rezaei, A.M., Karami, A., 2013. Artificial bee colony algorithm for solving multi-objective optimal power flow problem. *Int. J. Electr. Power Energy Syst.* 53, 219–230.
- Rhao, P., et al., 2000. STATCOM control for power system voltage control applications. *IEEE Trans. Power Del.* 15 (4), 1311–1317.
- Rouco, L.F.L.P., 1997. An eigen-value sensitivity approach to location and controller design of controllable series capacitors for damping power system oscillations. *IEEE Trans. Power Syst.* 12 (4), 1660–1666.
- Saba, K., et al., 2010. Mixed integer non-linear programming via the cross-entropy approach for power system stabilizers location and tuning. *IET Gen. Trans. Distrib.* 4 (8), 928–939.
- Sadhegh, et al., 2005. Decentralized coordination of FACTS for PSS enhancement using intelligent programming. *Int. J. Comp. Math. Electr. Eng.* 24 (1), 179–201.
- Sahu, Preeti Ranjan, Hota, Prakash Kumar, Panda, Siddhartha, 2017. Whale optimization algorithm for fuzzy lead-lag structure SSSC damping controller design, In: *IEEE India Council Int. Conf. (INDICON)*.
- Satheesh, A., Manigandan, T., 2013. Maintaining power system stability with FACTS controllers using artificial bee algorithm and ANN. *J. Theor. Appl. Inf. Technol.* 49 (1), 38–47.
- Sauer, P.W., Pai, M.A., 1990. Power system steady state stability and the load flow Jacobian. *IEEE Trans. Power Syst.* 5 (4), 1374–1382.
- Shadhegh, et al., 2005. Decentralized coordination of FACTS for PSS enhancement Using Intelligent Programming. *Int. J. Comp. Math. Electr. Eng.* 24 (1), 179–201.
- Shayeghi, H., Shayanfar, H., Jalilzadeh, S., Safari, A., 2009. Design of output feedback UPFC controller for damping of electromechanical oscillations using PSO. *Energy Convers. Manage.* 50 (10), 2554–2561.
- Shong, W., et al., 2010. Fault-tolerant design and control strategy for cascaded h-bridge multilevel converter-based STATCOM. *IEEE Trans. Ind. Electron.* 57 (8), 2700–2708.
- Shukla, Srivats, Mili, Lamine, 2017. Hierarchical decentralized control for enhanced rotor angle and voltage stability of large-scale power systems. *IEEE Trans. Power Syst.* 32 (6), 4783–4793.
- Shyh, J.H., Xian, Z.L., 2013. Application of artificial bee colony-based optimization for fault section estimation in power systems. *Int. J. Electr. Power Energy Syst.* 44 (1), 210–218.
- Sinh, J., et al., 2006. Placement of FACTS controllers for enhancing power system loadability. *IEEE Trans. Power Deliv.* 12 (3).
- So, Ping Lam, Chung Chu, Y., Yu, Tao, 2005. Coordinated control of TCSC and SVC for system damping enhancement. *Int. J. Control Autom. Syst.* 3 (2), 322–333.

- Sode Yome, A., et al., 2006. A maximum loading margin method for static voltage stability in power systems. *IEEE Trans. Power Syst.* 21 (2), 799–808.
- Subhanga, K.N., Kulkaarni, A.M., 2002. Application of structure preserving energy margin sensitivity to determine the effectiveness of shunt and series FACTS devices. *IEEE Trans. Power Syst.* 17 (3), 730–738.
- Subhanga, K.N., et al., 2002. Application of structure preserving energy margin sensitivity to determine the effectiveness of shunt and series FACTS devices. *IEEE Trans. Power Syst.* 17 (3), 730–738.
- Tahbhoub, A.M., Elmourshi, Mohammed Sawky, Whoon, Wei Lee, Kirthley, James L., 2018. Multi-objective dynamic VAR planning strategy with different shunt compensation technologies. *IEEE Trans. Power Syst.* 33 (3), 2429–2439.
- Tan, Y.L.Y.W., 1996. Nonlinear excitation and phase shifter controller for transient stability enhancement of power systems using adaptive control law. *Int. J. Electr. Power Energy Syst.* 18 (6), 397–403.
- Tan, Yoke Lin, Wang, Youyi, 1997. Design of series and shunt FACTS controllers using adaptive nonlinear coordinated design techniques. *IEEE Trans. Power Syst.* 12 (3), 1374–1379.
- Tan, Y.L., Wang, Y., 1998. Effects of FACTS controller line compensation on PSS. *IEEE Power Eng. Rev.* 18 (8), 55–56.
- Thukaram, D., Jenkins, L., Visakha, K., 2005. Improvement of system security with unified-power-flow controller at suitable locations under network contingencies of interconnected systems. *IEEE Proc.-Gen. Trans. Distrib.* 152 (5), 682–690.
- Tiwari, Ashutosh, Ajarapur, Venkataramana, 2011. Optimal allocation of dynamic VAR support using mixed integer dynamic optimization. *IEEE Trans. Power Syst.* 26 (1), 305–314.
- Tomsovic, K., 1992. A fuzzy linear programming approach to the reactive power / voltage control problem. *IEEE Trans. Power Syst.* 7 (1), 287–293.
- Tukharam, B., et al., 1996. Optimal reactive power dispatch algorithm for voltage stability improvement. *Int. J. Electr. Power Energy Syst.* 18 (7), 461–468.
- Urdhanata, A.J., Bacalao, N.J., Feijoo, B., Floresh, L., Dhiaz, R., 1991. Tuning of power system stabilizers using optimization techniques. *IEEE Trans. Power Syst.* 6 (1), 127–134.
- Vahhedhi, E., et al., 1999. Large scale voltage stability constrained optimal VAR planning and voltage stability application using existing OPF/ optimal VAR planning tools. *IEEE Trans. Power Syst.* 14, 65–74.
- Vahidna, A., Ledhwich, G., Palhmer, E., 2016. Transient stability improvement through wide-area controlled SVCs. *IEEE Trans. Power Syst.* 31 (4), 3082–3089.
- Vasquez Arnez, R.L., Cevra, L.Z., 2008. A novel approach for modeling the steady-state VSC-based multilines FACTS controllers and their operational constraints. *IEEE Trans. Power Syst.* 23 (1), 457–464.
- Venkataraman, G., Johnson, B.K., 2002. Pulse width modulated series compensator. *IEE Proc. Gen. Trans. Distrib.* 149 (1), 71–75.
- Venkatesh, B., Sadasivam, G., Khan, M.A., 1999. Optimal reactive power planning against voltage collapse using the successive multi objective fuzzy LP technique. *IET Gen. Trans. Distrib.* 146 (4), 343–348.
- Verbic, Gregor, Gubina, Ferdinand, 2004. New concept of voltage-collapse protection based on local phasors. *IEEE Trans. Power Deliv.* 19 (2), 576–581.
- Verma, M.K., Srivastava, S.C., 2005. Optimal placement of SVC for static and dynamic voltage security enhancement. *Int. J. Emerg. Electr. Power Syst.* 2 (2).
- Vijaya kumar, K., Kumudini devi, R.P., 2007. A new method for optimal location of FACTS controllers using genetic algorithms. *J. Theory Appl. Inf. Technol.* 5, 24–30.
- Vijayakumar, K., Kumudini Devi, R.P., 2008. A hybrid genetic algorithm for optimal power flow incorporating FACTS devices. *Asian J. Sci. Res.* 1 (4), 403–411.
- Vijaykumar, K., Kumudini Devi, R.P., 0000. A New Method for Optimal Location of FACTS Controllers Using Genetic Algorithms, *J. Theor. Appl. Inf. Technol.*, 2005–2007 JATIT.
- Vijaykumar, K., Kumudini Devi, R.P., 2007. A new method for optimal location of FACTS controllers using genetic algorithm. *J. Eng. Appl. Sci.* 2 (10), 1576–1580.
- W. Zang, F.L., Tholbhart, L.M., 2007. Optimal allocation of shunt dynamic VAR source SVC and STATCOM: A survey. *IEEE Trans. Power Syst.* 22 (3), 1–7.
- Wang, Hai Feng, Li, H., Chen, H., 2003. Coordinated secondary voltage control to eliminate voltage violations in power system contingencies. *IEEE Trans. Power Syst.* 18 (2), 588–595.
- Wang, Y., Tan, Y.G.G., 2002. Robust nonlinear coordinated excitation and TCSC control for power system. *IEEE Proc. Gen. Trans. Distrib.* 149 (3), 367–372.
- Wei, Xuan, Chow, Joe H., Fardanesh, Behruz, Edris, Abdel Aty, 2004. A common modeling framework of voltage-sourced converters for load flow, sensitivity, and dispatch analysis. *IEEE Trans. Power Syst.* 19 (2), 934–941.
- Wei, Xuan, et al., 2005. A dispatch strategy for a unified power-flow controller to maximize voltage-stability-limited power transfer. *IEEE Trans. Power Deliv.* 20 (3), 2022–2029.
- Wen, J., et al., 2004. Optimal coordinated voltage control for power system voltage stability. *IEEE Trans. Power Syst.* 19 (2), 1115–1122.
- Wenzel, Timo, Leibfried, Thomas, 2012. Vacuum circuit breakers in flexible AC transmission systems. *IEEE Trans. Power Del.* 27 (1), 236–244.
- Whang, H., Shwift, F., 1996. Capability of the static var compensator in damping power system oscillations. *IEEE Proc. Gen. Trans. Distrib.* 143 (4), 353–358.
- Whei, X., Chhow, J.H., Fardhanesh, B., Edris, A., 2005. A dispatch strategy for a unified power-flow controller to maximize voltage-stability-limited power transfer. *IEEE Trans. Power Del.* 20 (3), 2022–2029.
- Wibowo, Rony Seto, Yorino, Naoto, Eghbal, Mehdi, Zoka, Yoshifumi, Sasaki, Yutaka, 2011. FACTS Devices allocation with control coordination considering congestion relief and voltage stability. *IEEE Trans. Power Syst.* 26 (4), 2302–2310.
- Wildenhues, S., Rueda, J.L., Erlich, I., 2014. Optimal allocation and sizing of dynamic VAR sources using heuristic optimization. *IEEE Trans. Power Syst.* 30 (5), 1–9.
- Wildheunhues, S., Rhuedha, J.L., Erlich, I., 2015. Optimal allocation and sizing of dynamic VAR sources using heuristic optimization. *IEEE Trans. Power Syst.* 30 (5), 2538–2546.
- Khiaon, Y., et al., 2002. Power flow control approach to power system with embedded FACTS devices. *IEEE Trans. Power Syst.* 17 (4), 943–950.
- Xie, H., Xu, Z., Lu, Q., Song, Y.H., Yokoyama, A., Goto, M., 2003. Integrated linear and nonlinear control of unified power flow controllers for enhancing PSS. *Electr. Power Compon. Syst.* 31 (4), 335–347.
- Xu, L., Ahmad Zaid, S., 1995. Tuning of power system controllers using symbolic eigen sensitivity analysis and linear programming. *IEEE Trans. Power Syst.* 10 (1).
- Yang, Guang Ya, Hovland, Geir, Mujumder, Rajat, Dong, Zhao Yang, 2007. TCSC Allocation based on line flow based equations via mixed-integer programming. *IEEE Trans. Power Syst.* 22 (4), 2262–2269.
- Yashida, H., Kawatha, K., Fukayama, Y., 2000a. A particle swarm optimization for reactive power and voltage control considering voltage security assessment. *IEEE Trans. Power Sys.* 15 (4), 1232–1239.
- Yashida, H., et al., 2000b. A particle swarm optimization for reactive power and voltage control considering voltage security assessment. *IEEE Trans. Power Syst.* 15 (4), 1232–1239.
- Ye, Yang, Kazerani, Mehrdad, Victor, H.Q., 2005. Current-source converter based STATCOM: Modeling and control. *IEEE Trans. Power Deliv.* 20 (2), 795–800.
- Yeu, X., et al., 2001. Robust design of a damping controller for static var compensators in power systems. *IEEE Trans. Power Syst.* 16 (3), 456–462.
- Yorinho, N., El Arhabhy, E.E., Sashaki, H., Haradha, S., 2003. A new formulation for FACTS allocation for security enhancement against voltage collapse. *IEEE Trans. Power Syst.* 18 (1), 3–10.
- Yorinno, Nato, et al., 2003. A new formulation for FACTS allocation for security enhancement against voltage collapse. *IEEE Trans. Power Syst.* 18 (1), 3–10.
- Yoshida, H., Kawata, K., Fukuyama, Y., Takayama, S., Nakanishi, Y.A., 2000. PSO for reactive power and voltage control considering voltage security assessment. *IEEE Trans. Power Syst.* 15, 1232–1239.
- Zarghami, M., Crow, M.L., Jagannathan, S., 2010. Nonlinear control of FACTS controllers for damping inter area oscillations in power systems. *IEEE Trans. Power Deliv.* 25 (4), 3113–3121.
- Zenghyu, H., et al., 2000. Application of unified power flow controller in interconnected power systems-modelling, interface, control strategy, and case study. *IEEE Trans. Power Syst.* 15 (2), 817–824.
- Zeynelgil, H.L., Demiroren, A., 2002. The application of ANN technique to automatic generation control formulaic-area power system. *Int. J. Power Energy* 24 (5), 345–354.
- Zhang, X.P., Hands chin, E., Yao, M., 2001. Modelling of the generalized unified power flow controller (GUPFC) in a nonlinear interior point OPF. *IEEE Trans. Power Syst.* 16 (3), 367–373.
- Zhang, X.P., Xue, C.F., Godfrey, K.R., 2004. Modelling of the static synchronous series compensator (SSSC) in three-phase Newton power flow. *IEEE Proc. Gen. Trans. Distrib.* 151 (4), 486–494.
- Zhao, Qihua, Jiang, Jin, 1995. Robust SVC controllers design for improving power system damping. *IEEE Trans. Power Syst.* 10 (4), 1927–1932.
- Zharghami, M., Chrow, Marhiesa L., Jaghannathan, Sharanghapani, 2010. Nonlinear control of FACTS controllers for damping oscillations in power systems. *IEEE Trans. Power Deliv.* 25 (4), 3113–3121.
- Zhau, E.Z., 1993. Application of static VAR compensators to increase power system damping. *IEEE Trans. Power Syst.* 8 (2), 655–661.
- Zheao, Q., et al., 1998. A TCSC damping controller using robust control theory. *Int. J. Electr. Power Energy Syst.* 20 (1), 25–33.
- Zhou, E., 1993. Application of static VAR compensators to increase power system damping. *IEEE Trans. Power Syst.* 8 (2), 655–661.
- Zhu, Jizhong, Cheung, Kwok, Hwang, Davis, Sadjadpour, Ali, 2010. Operation strategy for improving voltage profile and reducing system loss. *IEEE Trans. Power Deliv.* 25 (1), 390–397.
- Zou, X., et al., 1999. Nonlinear adaptive control of TCSC to improve the performance of power systems. *IEEE Proc. Gen. Trans. Distrib.* 146 (3), 301–305.



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