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Article

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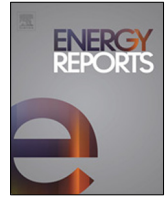
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A taxonomical review on impact assessment of optimally placed DGs and FACTS controllers in power systems

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ABSTRACT

In the present scenario of all over the world like develops and undeveloped countries are fastly used Distributed Generations (DGs) and Flexible Alternating Current Transmission Systems (FACTS) controllers in power systems for reactive power supports so that the overall power system performances are improved such as minimization of real and reactive power losses, environmental pollutions and maximization of loadability of system, power system stability, the short circuit capacity of the line and also enhancement of voltage profile, available power transfer capacity of the system, reliability as well as security of the system and more flexible operations of the system. This survey paper presents a taxonomical review on impact assessment of DGs and FACTS controllers in power systems from different power system performance viewpoints and reveals the current status of research work in this field.

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1. Introduction

DG, causally defined as small-scale electricity generation, in the close proximity area of a customer or where it is utilized. The different types of DGs are discussed by DISCO. The DG can be broadly classified on basis of real and reactive power delivered/absorbed as follows (Manoj and Puttaswamy, 2011; Mathad et al., 2013; Nagesh and Puttaswamy, 2013; Mena Kodsí and Cãñizares, 2003; Vijayakumar and Kumudinidevi, 0000; Abido, 2009; Kakkar et al., 2010; Narasimha Raju 1 et al., 2013; Singh et al., 2010; Singh 1 et al., 2014):

DG type 1: The real and reactive power delivered by DG to the system at unity PF operation is known as type 1 of DG. Like wind power source, tidal energy source and wave energy source etc.

DG type 2: Only real power delivered by DG to the system at 0.8 to 0.99 leading PF is known as a type 2 of DG system such as fuel cell, photovoltaic system, solar power plant etc.

DG type 3: If a DG system provides only reactive power support to the system at zero PF operation is known as type 3 of DG system such as synchronous motor in over excited mode, phase modifier circuit or synchronous condenser etc.

DG type 4: If a DG system provides real power support to the system and absorbs reactive power from system at 0.80 to 0.99

lagging operation is known as a type 4 of system such as double fed induction generator etc.

The DGs and FACTS controllers has several benefits like minimization of the real power loss and reactive power loss, enhance voltage stability of the system, reduce power system oscillation, reduce pollution as it uses cleaner energy resources, increase available power transfer capability, loadability of the system and bandwidth of operation, hence more flexible operation, more social and economic benefits etc. Besides the benefits, DG has some limitation also like small power generation, subsidiary system to the main system, mechanical maintenance required, and choice of type of distribution system greatly depends upon the environmental factors etc. From power quality point of view distributed system is employed for reduction of harmonics, prevent voltage sag and voltage swell, to shorten the transient period, minimization of voltage fluctuation and for PF improvement.

From last two decades, it is observed that the role of FACTS controllers in power system environment from power quality point of view is important. The various FACTS controller is used for improvement of power quality parameter in power system environments by providing the reactive power support to the system. So that the important issues are optimally placed of FACTS controllers provided the reactive power to the system. The power supply is based on the available reactive power in the system. Science the available reactive power in system is more that importance that the power quality parameters are better. When in case of shortage of reactive power in system than the power quality parameters are

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Nomenclature

Abbreviation

AI	Artificial Intelligence
ANN	Artificial neural network
DPFC	Distributed power flow controller
DGs	Distribution generations
DISCO	Distributed company
D-STATCOM	Distributed static synchronous compensator
GA	Genetic algorithm
GUPFC	Generalized unified power flow controller
GIPFC	Generalized interline power flow controllers
HVDC	High-voltage dc transmission
HPFC	Hybrid power flow controllers
IPFC	Interline power flow controllers
OPF	Optimal power flow
PST	Power system toolbox
PF	Power factor
TCSC	Thyristor controlled series compensator
TC-PAR	Thyristor controlled phase angle regulator
UPFC	Unified power flow controller
SSSC	Static synchronous series compensator
SVC	Static VAR compensator
STATCOM	Static synchronous compensator

Symbols

f	Supply frequency ($f = 50$ Hz)
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worst. So that FACTS controllers are having very important features to providing reactive power to the system for improvement of power quality of supply.

The various advantages of FACTS controllers are as follows: minimization of real and reactive power loss and power system oscillations, maximization of power system stability such as voltage, frequency and rotor angle stability in power systems, enhance system security, system power factor, system reliability, power flow control, loadability of system and available power transfer capability.

The various disadvantages of FACTS controllers are as follows: generation of harmonics due to all FACTS controller are based on power electronics circuitry, more capital cost of system due to filters are required, and more complexity in the system. The various FACTS controllers are developed by different generations. The first generation of FACTS controllers such as SVC, TCSC and TC-PAR etc., second generation of FACTS controllers such as SSSC, STATCOM, UPFC and IPFC etc. and third generation of FACTS controllers such as GUPFC, GIPFC, D-STATCOM and HPFC etc. The FACTS controllers are classified on the basis of connection diagram as follows (Manoj and Puttaswamy, 2011; Mathad et al., 2013; Nagesh and Puttaswamy, 2013; Mena Kods and C nizares, 2003; Vijayakumar and Kumudinidevi, 0000; Abido, 2009; Kakkar et al., 2010; Narasimha Raju1 et al., 2013; Singh et al., 2010; Singh1 et al., 2014; Ramakrishna Rao et al., 2014; Srivastava, 2010; Sivachandran et al., 2015; Ramesh1 and Jaya Laxmi, 2011; Mehta and Patel, 0000; Haribhai and Indrodia Nayna, 2012; Gad et al., 2012; Z rate-Mi nino et al., 2008; Hug-Glanzmann and Andersson, 2009; Fleming et al., 1981; Chansareewittaya and Jirapong, 2011; Farsang et al., 2004; Nguyen and Gianto, 2007; Kazemi and Badrzadeh, 2004; Farsangi and Mezamabadi-pour, 2007; Mehta et al., 1992; Martins and Lima, 1990; Vara Prasad and Chandra Sekhar, 2013; Chansareewittaya and Jirapong, 2012; Singh et al., 2009; Ara et al., 2011; Ajjarapu et al., 1994; Abido and Abdel-Magid, 2003; Berrouk et al., 2014;

Singh and David, 2001; Chatterjee and Ghosh, 2007; Mohamed and Jasmon, 1996; Canizares et al., 1998; Hsiao-Dong Chiang and Thorp, 1990; Swift and Wang, 1997; Messina et al., 1999; Obadina and Berg, 1990; Benzergua et al., 2007; Mustafa and Magaji, 2009; Cigre Working Group, 1977; An et al., 2007; Chatterjee and Ghosh, 2011; Fang et al., 2001; Wang et al., 1997; Messina et al., 2004, 2002; Candelo et al., 0000; Ammari et al., 2000; Mao-Xiaoming et al., 2006; So et al., 2005; Canizares and Faur, 1999; Luis Pagola et al., 1989; Arboleya et al., 2014; Esmaili et al., 2014; Chung et al., 2003; Tada et al., 1996; Valle' and Araujo, 2015; Hamouda et al., 1987; Tan and Wang, 1997; Kumar and Kumar, 0000; Chang, 2006; Shen et al., 2004; Fengwang et al., 2005; Choi and Jia, 2000; Phadke et al., 2012; Demello et al., 1980; Hsu and Chern-Linchen, 1987; Okamoto et al., 1995; Verma and Srivastava, 2005; Rouco and Pagola, 1997; Jain et al., 2009; Bian et al., 0000; Fang et al., 2009; Kalyan Kumar et al., 2007; Bamasak and Abido, 2004; Khodabakhshian et al., 0000; Lima et al., 2003; Oliveira et al., 2000; Zhou and Liang, 1999; Feng et al., 2000; Hao 1 et al., 2004; Yan-Jun et al., 2006; Glanzmann and Anderson, 2004; Hug-Glanzmann and Anderson, 2000; Simoes et al., 2009; Yorino et al., 2003; Chang and Huang, 1997; LashkarAra et al., 2013; Orfanogianni and Bacher, 2003; Yang et al., 2007; Yu and Lusan, 2004; Sharma, 2006; Zhang et al., 2017; Ramos et al., 2005; Ying-Yi and Wen-Ching, 1999; Liu et al., 2005; Najafi and Kazemi, 2006; Ramos et al., 2004; Kamwa et al., 2000; Pourbeik and Gibbard, 1998; Park et al., 2005; Lei et al., 2001; Li et al., 2010; Mori and Goto, 2000; Vijakumar and Kumudinidevi, 2007; Sadeghzadeh et al., 1998; Sadegh and Lo, 2005; El Metwally et al., 2006; Harish Kiran et al., 2011; Etingov et al., 2007; Panda and Padhy, 2007; Cai et al., 2005; Ganguly et al., 2016; Du et al., 2010; Leung and Chung, 1999a; Kazemi et al., 0000; Chandrasekaran et al., 0000; Dash and Mishra, 2003; Vinoth Kumar and Mohamed Thameem Ansari, 2016; Nireekshana et al., 2012; Cai et al., 2004; Moradi and Fotuhi-Firuzabad, 2008; Nireekshana et al., 2016; Kazemi and Sohrforouzani, 2006; Mahdad et al., 2010; Fang and Ngan, 1999; Leung and Chung, 2000; Preetha Roselyn and Devaraj, 2014; Ravi and Rajaram, 2013; Packiasudha et al., 2017; Abdel-Magid et al., 1999; Nguyen et al., 2008; Ippolito and Siano, 2004; Hasanovic et al., 2004; Manikandan et al., 2007; Rezaee Jordehi, 2015; Singh et al., 2015; Pateni et al., 1999; Zhang and Coonick, 2000; Kaewniyompanit et al., 2004; Chen et al., 2003; Sebaa and Boudour, 2008; Panda et al., 2007; Saravanan et al., 2005; Nguyen and Kandlawala, 2009; Panda and Ardil, 2008; Bakhshi et al., 0000; Panda and Padhy, 2006; Cai and Erlich, 2006; Mahmoud Outkati and Lo, 2005; Auchariyamet and Sirisumrannukul, 2009; Ngan and Fang, 1999; Hasanv et al., 0000; Raminrez et al., 2002; Zhang et al., 2007; Al-Awami et al., 2007; Sreedharan et al., 2011; Cai and Erlich, 2005; Singh et al., 2015; Bhattacharyya and Kumar, 2016; Bhattacharyya et al. Bhattacharyya, Gupta, Kumar, 2014b; Li et al., 1999; Santiago-Luna and Cedeno-Maldonado, 0000; Ramirez et al., 2002; Oudalov and Korba, 2005; Abdel Magid et al., 2000; Naceri et al., 2011; Ngamroo, 2005; Nguyen and Gianto, 2008; Carlisle and El Keib, 2000; Dash et al., 1999; Mazouz and Midoun, 2011; Falaghi et al., 2009; Gerbex et al., 0000; Abido, 2000; Patjoshi et al., 0000; Chen, 1996; Gitizadeh and Kalanta, 2008; Nair and Nambiar, 2002; Leung and Chung, 1999b; Surender Reddy et al., 2010; Guo and Li, 2009; Khan et al., 2003; Senjyu et al., 1999; Inkollu and Kota, 2016; Shaheen et al., 2008; Rashed et al., 2007; Bhattacharyya and Gupta, 2014a; Kalyani et al., 2006; Nanda Kumar and Dhanasekaran, 2014; Alamelu and Kumudhini Devi, 2008; Ippolito et al., 2006; A hybrid Meta-Heuristic, 2009);

Series connected FACTS controllers: the various FACTS controllers such as TCSC and TCPAR are the examples of series connected FACTS controllers (Manoj and Puttaswamy, 2011; Mathad et al., 2013; Nagesh and Puttaswamy, 2013; Mena Kods and C nizares, 2003; Vijayakumar and Kumudinidevi, 0000; Abido, 2009; Kakkar et al., 2010; Narasimha Raju1 et al., 2013; Singh et al., 2010; Singh1 et al., 2014).

Shunt connected FACTS controllers: the various FACTS controllers such as SVC, STATCOM, D-STATCOM and DVR are the example of a series connected FACTS controllers (Ramakrishna Rao et al., 2014; Srivastava, 2010; Sivachandran et al., 2015; Ramesh1 and Jaya Laxmi, 2011; Mehta and Patel, 0000; Haribhai and Indrodia Nayna, 2012; Gad et al., 2012; Zárate-Miñano et al., 2008; Hug-Glanzmann and Andersson, 2009; Fleming et al., 1981).

Series-series connected FACTS controllers: the various FACTS controllers such as IPFC and GIPFC are the example of series-series connected FACTS controllers (Chansareewittaya and Jirapong, 2011; Farsang et al., 2004; Nguyen and Gianto, 2007; Kazemi and Badrzadeh, 2004; Farsangi and Mezamabadi-pour, 2007).

Shunt-series connected FACTS controllers: the various FACTS controllers such as UPFC, GUPFC and HPFC are the example of shunt-series connected FACTS controllers (Mehta et al., 1992; Martins and Lima, 1990; Vara Prasad and Chandra Sekhar, 2013; Chansareewittaya and Jirapong, 2012; Singh et al., 2009).

So that FACTS controller such as TCSC, SVC, TC-PAR, SSSC, STATCOM, D-STATCOM, UPFC, IPFC, GUPFC, HPFC etc. are used for improvement of the power system performance by providing reactive power support to system. Such FACTS controller have important role in improvement of power system performance. That is major advantage of this controller. The disadvantage of such FACTS controllers are the generation of harmonics since FACTS controllers configuration are based on power electronics switching converters (AC voltage regulator and voltage source inverter). Therefore more costlier due to filter are required in the system for elimination of current and voltage harmonics. The FACTS controller have better performance when they are optimally located and properly coordinated in the system. So that to various methods for optimal location and proper coordination of FACTS controllers in power system from different power system performance viewpoints are survey in the various open literatures (Manoj and Puttaswamy, 2011; Mathad et al., 2013; Nagesh and Puttaswamy, 2013; Mena Kodsí and Cānizares, 2003; Vijayakumar and Kumudinidevi, 0000; Abido, 2009; Kakkar et al., 2010; Narasimha Raju1 et al., 2013; Singh et al., 2010; Singh1 et al., 2014; Ramakrishna Rao et al., 2014; Srivastava, 2010; Sivachandran et al., 2015; Ramesh1 and Jaya Laxmi, 2011; Mehta and Patel, 0000; Haribhai and Indrodia Nayna, 2012; Gad et al., 2012; Zárate-Miñano et al., 2008; Hug-Glanzmann and Andersson, 2009; Fleming et al., 1981; Chansareewittaya and Jirapong, 2011; Farsang et al., 2004; Nguyen and Gianto, 2007; Kazemi and Badrzadeh, 2004; Farsangi and Mezamabadi-pour, 2007; Mehta et al., 1992; Martins and Lima, 1990; Vara Prasad and Chandra Sekhar, 2013; Chansareewittaya and Jirapong, 2012; Singh et al., 2009; Ara et al., 2011; Ajjarapu et al., 1994; Abido and Abdel-Magid, 2003; Berrouk et al., 2014; Singh and David, 2001; Chatterjee and Ghosh, 2007; Mohamed and Jasmon, 1996; Canizares et al., 1998; Hsiao-Dong Chiang and Thorp, 1990; Swift and Wang, 1997; Messina et al., 1999; Obadina and Berg, 1990; Benzergua et al., 2007; Mustafa and Magaji, 2009; Cigre Working Group, 1977; An et al., 2007; Chatterjee and Ghosh, 2011; Fang et al., 2001; Wang et al., 1997; Messina et al., 2004, 2002; Candelo et al., 0000; Ammari et al., 2000; Mao-Xiaoming et al., 2006; So et al., 2005; Canizares and Faur, 1999; Luis Pagola et al., 1989; Arboleya et al., 2014; Esmaili et al., 2014; Chung et al., 2003; Tada et al., 1996; Valle' and Araujo, 2015; Hamouda et al., 1987; Tan and Wang, 1997; Kumar and Kumar, 0000; Chang, 2006; Shen et al., 2004; Fengwang et al., 2005; Choi and Jia, 2000; Phadke et al., 2012; Demello et al., 1980; Hsu and Chern-Linchen, 1987; Okamoto et al., 1995; Verma and Srivastava, 2005; Rouco and Pagola, 1997; Jain et al., 2009; Bian et al., 0000; Fang et al., 2009; Kalyan Kumar et al., 2007; Bamasak and Abido, 2004; Khodabakhshian et al., 0000; Lima et al., 2003; Oliveira et al., 2000; Zhou and Liang, 1999; Feng et al., 2000; Hao 1 et al., 2004; Yan-Jun et al., 2006; Glanzmann and Anderson, 2004; Hug-Glanzmann and Anderson, 2000; Simoes et

al., 2009; Yorino et al., 2003; Chang and Huang, 1997; LashkarAra et al., 2013; Orfanogianni and Bacher, 2003; Yang et al., 2007; Yu and Lusan, 2004; Sharma, 2006; Zhang et al., 2017; Ramos et al., 2005; Ying-Yi and Wen-Ching, 1999; Liu et al., 2005; Najafi and Kazemi, 2006; Ramos et al., 2004; Kamwa et al., 2000; Pourbeik and Gibbard, 1998; Park et al., 2005; Lei et al., 2001; Li et al., 2010; Mori and Goto, 2000; Vijakumar and Kumudinidevi, 2007; Sadehgzadeh et al., 1998; Sadeh and Lo, 2005; El Metwally et al., 2006; Harish Kiran et al., 2011; Etingov et al., 2007; Panda and Padhy, 2007; Cai et al., 2005; Ganguly et al., 2016; Du et al., 2010; Leung and Chung, 1999a; Kazemi et al., 0000; Chandrasekaran et al., 0000; Dash and Mishra, 2003; Vinoth Kumar and Mohamed Thameem Ansari, 2016; Nireekshana et al., 2012; Cai et al., 2004; Moradi and Fotuhi-Firuzabad, 2008; Nireekshana et al., 2016; Kazemi and Sohrforouzani, 2006; Mahdad et al., 2010; Fang and Ngan, 1999; Leung and Chung, 2000; Preetha Roselyn and Devaraj, 2014; Ravi and Rajaram, 2013; Packiasudha et al., 2017; Abdel-Magid et al., 1999; Nguyen et al., 2008; Ippolito and Siano, 2004; Hasanovic et al., 2004; Manikandan et al., 2007; Rezaee Jordehi, 2015; Singh et al., 2015; Pateni et al., 1999; Zhang and Coonick, 2000; Kaewniyompanit et al., 2004; Chen et al., 2003; Sebaa and Boudour, 2008; Panda et al., 2007; Saravanan et al., 2005; Nguyen and Kandlawala, 2009; Panda and Ardil, 2008; Bakhshi et al., 0000; Panda and Padhy, 2006; Cai and Erlich, 2006; Mahmoud Outkati and Lo, 2005; Auchariyemet and Sirisumrannukul, 2009; Ngan and Fang, 1999; Hasany et al., 0000; Raminrez et al., 2002; Zhang et al., 2007; Al-Awami et al., 2007; Sreedharan et al., 2011; Cai and Erlich, 2005; Singh et al., 2015; Bhattacharyya and Kumar, 2016; Bhattacharyya et al. Bhattacharyya, Gupta, Kumar, 2014b; Li et al., 1999; Santiago-Luna and Cedeno-Maldonado, 0000; Ramirez et al., 2002; Oudalov and Korba, 2005; Abdel Magid et al., 2000; Naceri et al., 2011; Ngamroo, 2005; Nguyen and Gianto, 2008; Carlisle and El Keib, 2000; Dash et al., 1999; Mazouz and Midoun, 2011; Falaghi et al., 2009; Gerbex et al., 0000; Abido, 2000; Patjoshi et al., 0000; Chen, 1996; Gitizadeh and Kalanta, 2008; Nair and Nambiar, 2002; Leung and Chung, 1999b; Surender Reddy et al., 2010; Guo and Li, 2009; Khan et al., 2003; Senjyu et al., 1999; Inkollu and Kota, 2016; Shaheen et al., 2008; Rashed et al., 2007; Bhattacharyya and Gupta, 2014a; Kalyani et al., 2006; Nanda Kumar and Dhanasekaran, 2014; Alamelu and Kumudhini Devi, 2008). The various applications of FACTS controllers are as follows: minimization of real and reactive power loss, maximization of loadability of system, maximization of availability of power transfer capacity, enhance power system stability, enhance power system security, enhance power system reliability, reduce the power system oscillations, improve power factor of the system, improve power quality parameters such as voltage swell and voltage sag etc. The taxonomical review on optimal placed of FACTS controllers in power system environments from different power system performance viewpoints such as power quality parameters is presented in Table 1. The various methods/techniques such as conventional methods, optimization methods, artificial intelligence techniques and hybrid techniques for the optimal placement and sizing of DGs and FACTS controllers in power systems from the enhancement of different power system performance viewpoints are discussed in taxonomical format as in Tables 1–4. The various techniques are discussed for optimal placement and sizing of DGs and FACTS controllers in power systems are as follows:

The various conventional methods such as eigen value method, eigen vector method, modal index method and optimal power flow method etc. are discussed in taxonomical format in Section 2 for optimal placement and sizing of DGs and FACTS controllers in power systems from different power system performance viewpoints. The optimization methods such as linear programming, non-linear programming, mixed integer non-linear programming, dynamic programming and dual programming etc. are discussed in

Table 1

Taxonomical review for optimization techniques regarding with impact assessment of optimally placed DGs and FACTS controllers in power system from different power systems performances viewpoints.

Reference	Power system performances	Methods	DGs/Types of FACTS controllers are used	IEEE test system	Future work
Manoj and Dr. Puttaswamy (2011)	Power system loadability	Optimal power flow	SSSC, TCSC, UPFC	IEEE-39 Bus	Hybrid techniques
Mathad et al. (2013)	Controlling the active and reactive power flows	Controlling method	SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Realistic load models
Nagesh and Puttaswamy (2013)	Enhance of voltage stability margin	Controlling method	DG-3, STATCOM and SVC	IEEE-14 Bus	Multi-objective task
Mena Kodsi and Cañizares (2003)	Modeling and simulation	added, modeled	PSS, TCSC, SVC	IEEE-14 Bus	Practical implementation
Vijayakumar and Kumudini Devi (0000)	Optimal allocation	Newton–Raphson	TCSC, UPFC	IEEE-9 Bus	Hybrid techniques
Abido (2009)	Performance comparison of different FACTS	Sensitivity analysis	SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Realistic load models
Kakkar et al. (2010)	Analyze the current trends in FACTS and D-FACTS	Modal analysis	SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Multi-objective task
Narasimha Raju I et al. (2013)	Power system stability	Optimal power flow	UPFC, IPFC	IEEE-14 Bus	Practical implementation
Singh et al. (2010)	Power system loadability	Optimal power flow	SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Practical implementation
Singh I et al. (2014)	Enhance controllability, stability, and power transfer capability of ac transmission	Optimal power flow	DG-3, STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Hybrid techniques
Ramakrishna Rao et al. (2014)	Stability enhancement	Optimal power flow	DG-4, STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Realistic load models
Srivastava (2010)	Advanced power electronics	Controlling method	STATCOM, SSSC, TCSC, UPFC, GUPFC	IEEE-14 Bus	Multi-objective task
Sivachandran et al. (2015)	Improvement of power system stability	Controlling method	SSSC, TCSC, , SVC, DPFC	IEEE-39 Bus	Practical implementation
Ramesh I and Jaya Laxmi (2011)	Power transmission capability	comprehensive analysis	DG-2, HVDC, UPFC	IEEE-14 Bus	Realistic load models
Mehta and Patel (0000)	Static voltage improvement	Newton–Raphson	DG-4, STATCOM	IEEE-6 Bus	Multi-objective task
Haribhai and Indrodia Nayna (2012)	Control of wind power station	Optimal power flow	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Practical implementation
Gad et al. (2012)	Reduction of total system reactive power loss and real power performance index	Sensitivity analysis	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Practical implementation
Zárate-Miñano et al. (2008)	Security enhancement	Optimal power flow	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Hybrid techniques
Hug-Glanzmann and Andersson (2009)	System security	Sensitivity analysis	SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Realistic load models
Fleming et al. (1981)	Damping of power system	Eigen value	SSSC, TCSC, UPFC, SVC	IEEE-6 Bus	Practical implementation
Chansareewittaya and Jirapong (2011)	Power transfer capability	Optimal power flow	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-57 Bus	Practical implementation
Farsang et al. (2004)	Damping inter area oscillation	Index analysis	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-16 Bus	Hybrid techniques
Nguyen and Gianto (2007)	Small signal stability	Eigen value	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Realistic load models
Kazemi and Badrzadeh (2004)	Reactive power	Eigen value	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Multi-objective task
Farsangi and Mezamabadi-pour (2007)	Stability	Modal analysis	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-6 Bus	Practical implementation
Mehta et al. (1992)	Voltage stability margin	Sensitivity analysis	STATCOM	IEEE-57 Bus	Practical implementation
Martins and Lima (1990)	Power system damping	Sensitivity analysis	PSS, TCSC, SVC	IEEE-69 Bus	Practical implementation
Vara Prasad and Chandra Sekhar (2013)	System loadability	Repeated power flow	PSS, TCSC, SVC	IEEE-14 Bus	Hybrid techniques
Chansareewittaya and Jirapong (2012)	Power transfer capability	Optimal power flow	PSS, TCSC, SVC	IEEE-6 Bus	Realistic load models
Singh et al. (2009)	Power system oscillation	Sensitivity analysis	SSSC, TCSC, UPFC	IEEE-57 Bus	Practical implementation
Ara et al. (2011)	Real and reactive power	Optimal power flow	SSSC, TCSC, UPFC	IEEE-16 Bus	Practical implementation
Ajjarapu et al. (1994)	Reactive power support	Sensitivity analysis	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Hybrid techniques
Abido and Abdel-Magid (2003)	Power system stability	Eigen value	PSS, TCSC, SVC	IEEE-14 Bus	Hybrid techniques
Berrouk et al. (2014)	Voltage stability	Newton–Raphson	SSSC, TCSC, UPFC	IEEE-37 Bus	Realistic load models
Singh and David (2001)	Power flow	Sensitivity analysis	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-57 Bus	Multi-objective task
Chatterjee and Ghosh (2007)	Transient stability	Sensitivity analysis	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Practical implementation
Mohamed and Jasmon (1996)	Reactive power	Index analysis	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Hybrid techniques

(continued on next page)

Table 1 (continued)

Canizares et al. (1998)	Reactive power	Sensitivity analysis	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-37 Bus	Realistic load models
Hsiao-Dong Chiang and Thorp (1990)	Stability	Eigen value	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-57 Bus	Multi-objective task
Swift and Wang (1997)	Oscillation stability	Modal analysis	SSSC, TCSC, UPFC, SVC	IEEE-16 Bus	Practical implementation
Messina et al. (1999)	Inter area oscillation	Modal analysis	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-16 Bus	Practical implementation
Obadina and Berg (1990)	System stability	Residue analysis	PSS, TCSC, SVC	IEEE-9 Bus	Hybrid techniques
Benzergua et al. (2007)	Voltage security enhancement	Sensitivity analysis	DG-4, PSS, TCSC, SVC	246 Bus Indian test system	Realistic load models
Mustafa and Magaji (2009)	Damping power system oscillation	Residue analysis	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-16 Bus	Practical implementation
Cigre Working Group (1977)	Power system loadability	Eigen value	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-37 Bus	Practical implementation
An et al. (2007)	Reactive power	Sensitivity analysis	SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Hybrid techniques
Chatterjee and Ghosh (2011)	Transient stability	Sensitivity analysis	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-16 Bus	Hybrid techniques
Fang et al. (2001)	Power flow	Newton–Raphson	SSSC, TCSC, UPFC, SVC	IEEE-16 Bus	Realistic load models
Wang et al. (1997)	Power system stability	Modal analysis	SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Multi-objective task
Messina et al. (2004)	Inter area oscillation	Residue analysis	PSS, TCSC, SVC	IEEE-39 Bus	Practical implementation
Messina et al. (2002)	Damp out inter area oscillation	Modal analysis	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Hybrid techniques
Candelo et al. (0000)	Reactive power and voltage control	Sensitivity analysis	DG-1, STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-37Bus	Realistic load models
Ammari et al. (2000)	Damping power system oscillation	Residue analysis	SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Practical implementation
Mao-Xiaoming et al. (2006)	Inter area oscillation	Modal analysis	PSS, TCSC, SVC	IEEE-16 Bus	Practical implementation
So et al. (2005)	Dynamic performance of power system	Sensitivity	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-16 Bus	Practical implementation
Canizares and Faur (1999)	Voltage collapse	Sensitivity analysis	DG-4, SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Hybrid techniques
Luis Pagola et al. (1989)	Stability	Eigen value	PSS, TCSC, SVC	IEEE-9 Bus	Realistic load models
Arboleya et al. (2014)	Power flow	Optimal power flow	PSS, TCSC, SVC	IEEE-9 Bus	Practical implementation
Esmaili et al. (2014)	Voltage and transient stability	Optimal power flow	PSS, TCSC, SVC	IEEE-16 Bus	Practical implementation
Chung et al. (2003)	Power system damping	Eigen value	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-16 Bus	Hybrid techniques
Tada et al. (1996)	Damping inter area oscillation	Modal analysis	SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Hybrid techniques
Valle' and Araujo (2015)	Small signal stability	Optimal power flow	SSSC, TCSC, UPFC, SVC	IEEE-30 Bus	Realistic load models
Hamouda et al. (1987)	Power system oscillation	Eigen value	SSSC, TCSC, UPFC, SVC	IEEE-16 Bus	Multi-objective task
Tan and Wang (1997)	Transient stability	Sensitivity analysis	SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Realistic load models
Kumar and Kumar (0000)	Available power transfer capability	Optimal power flow	SSSC, TCSC, UPFC, SVC	IEEE-16 Bus	Multi-objective task
Chang (2006)	Power system oscillation	Eigen value	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Practical implementation
Shen et al. (2004)	Damping of power system	Eigen value	SSSC, TCSC, UPFC, SVC	IEEE-30 Bus	Hybrid techniques
Fengwang et al. (2005)	Voltage stability	Sensitivity analysis	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-16 Bus	Realistic load models
Choi and Jia (2000)	Power system oscillation	Sensitivity analysis	SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Practical implementation
Phadke et al. (2012)	Small signal stability	Eigen value	SSSC, TCSC, UPFC, SVC	IEEE-118 Bus	Practical implementation
Demello et al. (1980)	Transient stability	Eigen value	PSS, TCSC, SVC	IEEE-14 Bus	Practical implementation
Messina et al. (2002)	Power system inter area oscillation	Modal analysis	PSS, TCSC, SVC	IEEE-9 Bus	Hybrid techniques
Hsu and Chern-Linchen (1987)	Damping power system oscillation	Eigen value	DG-3, PSS, TCSC, SVC	IEEE-300 Bus	Realistic load models
Okamoto et al. (1995)	Small signal stability	Index analysis	SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Practical implementation
Verma and Srivastava (2005)	Voltage stability	Sensitivity analysis	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-30 Bus	Practical implementation
Rouco and Pagola (1997)	Damping power system oscillation	Eigen value	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-16 Bus	Hybrid techniques
Jain et al. (2009)	Available power transfer capability	Sensitivity analysis	SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Realistic load models
Bian et al. (0000)	Power system oscillation	Eigen value	PSS, TCSC, SVC	IEEE-118 Bus	Practical implementation
Fang et al. (2009)	Stability of power system	Sensitivity analysis	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Practical implementation
Kalyan Kumar et al. (2007)	Damp out power system oscillation	Modal analysis	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Practical implementation
Bamasak and Abido (2004)	Power system stability	Eigen value	PSS, TCSC, SVC	IEEE-300 Bus	Hybrid techniques
Khodabakhshian et al. (0000)	Power system stability	Mixed integer non-linear optimization	SSSC, TCSC, UPFC, SVC	IEEE-30 Bus	Realistic load models
Lima et al. (2003)	Active power flow	Mixed integer optimization	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-16 Bus	Realistic load models
Oliveira et al. (2000)	Minimize generation cost	Dynamic optimization	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Practical implementation
Zhou and Liang (1999)	Small-signal stability	Non-linear optimization	PSS, TCSC, SVC	IEEE-118 Bus	Practical implementation
Feng et al. (2000)	Voltage collapse	Linear optimization	PSS, TCSC, SVC	IEEE-14 Bus	Hybrid techniques
Hao 1 et al. (2004)	System loadability	Non-linear optimization	SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Realistic load models
Yan-Jun et al. (2006)	Voltage stability	Linear optimization	PSS, TCSC, SVC	IEEE-9 Bus	Practical implementation

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Table 1 (continued)

Glanzmann and Anderson (2004)	Optimal power flow	Linear optimization	DG-3, PSS, TCSC, SVC	IEEE-300 Bus	Hybrid techniques
Hug-Glanzmann and Anderson (2000)	Security enhancement	Linear optimization	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Realistic load models
Simoes et al. (2009)	Power oscillation damping	Non-linear optimization	PSS, TCSC, SVC	IEEE-30 Bus	Multi-objective task
Yorino et al. (2003)	Power system security	Integer and mixed-integer optimization	SSSC, TCSC, UPFC, SVC	IEEE-16 Bus	Practical implementation
Chang and Huang (1997)	Voltage stability	Dynamic optimization	DG-3, PSS, TCSC, SVC	IEEE-9 Bus	Practical implementation
LashkarAra et al. (2013)	Power system damping	Non-linear optimization	PSS, TCSC, SVC	IEEE-118 Bus	Hybrid techniques
Orfanogianni and Bacher (2003)	Voltage and reactive power control	Dynamic optimization	SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Realistic load models
Yang et al. (2007)	Power system security	Mixed integer optimization	PSS, TCSC, SVC	IEEE-9 Bus	Multi-objective task
Yu and Lusan (2004)	Damping of power system	Dynamic optimization	SSSC, TCSC, UPFC, SVC	IEEE-300 Bus	Practical implementation
Oliveira et al. (2000)	Thermal generation cost	Dynamic optimization	PSS, TCSC, SVC	IEEE-30 Bus	Realistic load models
Sharma (2006)	Power system security	Mixed integer optimization	SSSC, TCSC, UPFC, SVC	IEEE-16 Bus	Multi-objective task
Zhang et al. (2017)	Power system stability	Linear optimization	SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Practical implementation
Ramos et al. (2005)	Electro mechanical damping	Non-linear optimization	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Practical implementation
Ying-Yi and Wen-Ching (1999)	Small signal stability	Non-linear optimization	SSSC, TCSC, UPFC, SVC	IEEE-118 Bus	Hybrid techniques
Liu et al. (2005)	Electro mechanical oscillation	Non-linear optimization	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Realistic load models
Nguyen and Gianto (2007)	Power system damping	Linear optimization	SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Practical implementation
Najafi and Kazemi (2006)	Dynamic stability improvement	Linear optimization	SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Practical implementation
Ramos et al. (2004)	Power system damping	Linear optimization	PSS, TCSC, SVC	IEEE-118 Bus	Hybrid techniques
Kamwa et al. (2000)	Power system damping	Linear optimization	DG-2, PSS, TCSC, SVC	IEEE-14 Bus	Realistic load models
Pourbeik and Gibbard (1998)	Rotor mode oscillation	Linear optimization		IEEE-69 Bus	Multi-objective task
Park et al. (2005)	Transient stability improvement	Non-linear optimization	SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Practical implementation
Lei et al. (2001)	Dynamic stability	Non-linear optimization	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-118 Bus	Practical implementation
Li et al. (2010)	Power system stability	Bacterial foraging algorithm	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Practical implementation
Mori and Goto (2000)	Voltage	Parallel tabu-search algorithm	SSSC, TCSC, UPFC	IEEE-69 Bus	Hybrid techniques
Vijakumar and Kumudini (2007)	Reduction of generation cost	Genetic algorithm	SSSC, TCSC, UPFC, SVC		Realistic load models
Sadeghzadeh et al. (1998)	Voltage and loss	Fuzzy logic	STATCOM and SVC	IEEE-14 Bus	Practical implementation
Sadegh and Lo (2005)	Power system stability	Fuzzy logic	PSS, TCSC, SVC	IEEE-14 Bus	Practical implementation
El Metwally et al. (2006)	Power system balance	Artificial neural network	DG-2, DG-3, TCSC, UPFC	IEEE-9 Bus	Hybrid techniques
Harish Kiran et al. (2011)	Minimization of system cost	Particle swarm optimization	SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Hybrid techniques
Etingov et al. (2007)	Power system stability	Artificial neural network	SSSC, TCSC, UPFC, SVC	IEEE-118 Bus	Multi-objective task
Panda and Padhy (2007)	Power oscillation damping	Genetic algorithm	UPFC, IPFC	IEEE-14 Bus	Practical implementation
Cai et al. (2005)	Power oscillation damping	Genetic algorithm	SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Practical implementation
Ganguly et al. (2016)	Frequency and power control	Fuzzy logic	STATCOM, SSSC, TCSC, UPFC, SVC		Hybrid techniques
Du et al. (2010)	Damp power system oscillation	Artificial fish swarm optimization	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Realistic load models
Leung and Chung (1999a)	Reduction of generation cost	Genetic algorithm	STATCOM, SSSC, TCSC, UPFC, SVC, GUPFC	IEEE-14 Bus	Multi-objective task
Kazemi et al. (0000)	Power oscillation damping	Genetic algorithm	SSSC, TCSC, UPFC, SVC, DPFC	IEEE-9 Bus	Practical implementation
Chandrasekaran et al. (0000)	Optimal power flow	Particle swarm optimization	HVDC, UPFC	IEEE-39 Bus	Realistic load models
Dash and Mishra (2003)	Electro-mechanical oscillation	Fuzzy logic	STATCOM	IEEE-6 Bus	Multi-objective task
Vinoth Kumar and Mohamed Thameem Ansari (2016)	Frequency	Fuzzy logic	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Realistic load models
Nireekshana et al. (2012)	Available power transfer capability	Genetic algorithm	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Multi-objective task
Cai et al. (2004)	Reduction of generation cost	Genetic algorithm	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Practical implementation
Moradi and Fotuhi-Firuzabad (2008)	Cost and system reliability	Particle swarm optimization	DG-2, SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Practical implementation
Nireekshana et al. (2016)	Available power transfer capability	Cat swarm optimization	SSSC, TCSC, UPFC, SVC	IEEE-6 Bus	Hybrid techniques
Kazemi and Sohrforouzani (2006)	Inter area oscillation	Fuzzy logic	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Realistic load models

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Table 1 (continued)

Mahdad et al. (2010)	Optimal power flow	Genetic algorithm	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Multi-objective task
Fang and Ngan (1999)	Steady state performance	Fuzzy logic	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Practical implementation
Leung and Chung (2000)	Optimal power flow	Genetic algorithm	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Realistic load models
Preetha Roselyn and Devaraj (2014)	Voltage stability	Genetic algorithm	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Multi-objective task
Ravi and Rajaram (2013)	Voltage stability	Particle swarm optimization	DG-4, STATCOM	IEEE-57 Bus	Practical implementation
Packiasudha et al. (2017)	Minimum system loss	Gravitational search algorithm	PSS, TCSC, SVC	IEEE-57 Bus	Practical implementation
Abdel-Magid et al. (1999)	Power system stability	Genetic algorithm	PSS, TCSC, SVC	IEEE-6 Bus	Practical implementation
Nguyen et al. (2008)	Power system disturbance	Genetic algorithm	DG-3, PSS, TCSC, SVC	IEEE-14 Bus	Practical implementation
Ippolito and Siano (2004)	Damping of power system oscillation	Genetic algorithm	SSSC, TCSC, UPFC	IEEE-14 Bus	Hybrid techniques
Hasanovic et al. (2004)	Power system security	Genetic algorithm	SSSC, TCSC, UPFC	IEEE-39 Bus	Realistic load models
Manikandan et al. (2007)	Available power transfer capability	Particle swarm optimization	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Multi-objective task
Rezaee Jordehi (2015)	Reactive power	Particle swarm optimization	DG-1, PSS, TCSC, SVC	IEEE-6 Bus	Practical implementation
Singh et al. (2015b)	Optimal power flow	Particle swarm optimization	DG-3, SSSC, TCSC, UPFC	IEEE-14 Bus	Realistic load models
Pateni et al. (1999)	Improve loadability of network	Genetic algorithm	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Multi-objective task
Zhang and Coonick (2000)	System small signal stability	Genetic algorithm	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Practical implementation
Kaewniyompanit et al. (2004)	Power system stability	Genetic algorithm	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Practical implementation
Chen et al. (2003)	Power system damping	Fuzzy logic	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Hybrid techniques
Sebaa and Boudour (2008)	Power system dynamic stability	Genetic algorithm	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-57 Bus	Realistic load models
Panda et al. (2007)	Power system stability	Particle swarm optimization	SSSC, TCSC, UPFC, SVC	IEEE-57 Bus	Hybrid techniques
Saravanan et al. (2005)	System loadability	Particle swarm optimization	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-37 Bus	Hybrid techniques
Nguyen and Kandlawala (2009)	Dynamic performance of power system	Fuzzy logic	DG-3, PSS, TCSC, SVC	IEEE-9 Bus	Multi-objective task
Panda and Ardil (2008)	Power system stability	Particle swarm optimization	PSS, TCSC, SVC	IEEE-14 Bus	Practical implementation
Bakhshi et al. (0000)	Transient stability of power system	Fuzzy logic	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Practical implementation
Panda and Padhy (2006)	Power system stability	Particle swarm optimization	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-57 Bus	Hybrid techniques
Cai and Erlich (2006)	Damping oscillation	Fuzzy logic	SSSC, TCSC, UPFC, SVC	IEEE-57 Bus	Realistic load models
Mahmoud Outkati and Lo (2005)	Power system stability	Fuzzy logic	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-37 Bus	Multi-objective task
Auchariyamet and Sirisumrannukul (2009)	Reactive power	Fuzzy logic	SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Practical implementation
Ngan and Fang (1999)	Dynamic performance of power system	Fuzzy logic	SSSC, TCSC, UPFC, SVC	IEEE-57 Bus	Realistic load models
Hasanv et al. (0000)	System stability and power system oscillation	Particle swarm optimization	DG-4, PSS, TCSC, SVC	IEEE-9 Bus	Multi-objective task
Raminrez et al. (2002)	Electro mechanical oscillation	Fuzzy logic	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Practical implementation
Zhang et al. (2007)	Voltage stability	Fuzzy logic	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Practical implementation
Al-Awami et al. (2007)	Power system stability	Particle swarm optimization	SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Practical implementation
Sreedharan et al. (2011)	Active power	Particle swarm optimization	DG-1, PSS, TCSC, SVC	IEEE-57 Bus	Practical implementation
Cai and Erlich (2005)	Transient stability and power system oscillation	Fuzzy logic	DG-3, STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-57 Bus	Hybrid techniques
Singh et al. (2015)	Power quality	Artificial neural network	DG-3, SSSC, TCSC, UPFC, SVC	IEEE-37 Bus	Realistic load models
Bhattacharyya and Kumar (2016)	Loadability	Gravitational search algorithm	PSS, TCSC, SVC	IEEE-9 Bus	Practical implementation
Bhattacharyya et al. (2014b)	Reactive powerflow	Genetic algorithm	PSS, TCSC, SVC	IEEE-57 Bus	Practical implementation
Li et al. (1999)	Power system stability	Fuzzy logic	PSS, TCSC, SVC	IEEE-9 Bus	Hybrid techniques
Santiago-Luna and Cedeno-Maldonado (0000)	System loadability	Fuzzy logic	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Hybrid techniques
Ramirez et al. (2002)	Dynamic stability margin	Fuzzy logic	SSSC, TCSC, UPFC, SVC	IEEE-57 Bus	Multi-objective task
Oudalov and Korba (2005)	Power flow	Fuzzy logic	SSSC, TCSC, UPFC, SVC	IEEE-37 Bus	Practical implementation
Abdel Magid et al. (2000)	Power system stability	Parallel tabu-search algorithm	SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Practical implementation

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Table 1 (continued)

Naceri et al. (2011)	Dynamic performance of power system	Fuzzy logic	SSSC, TCSC, UPFC, SVC	IEEE-57 Bus	Hybrid techniques
Ngamroo (2005)	Frequency stability	Parallel tabu-search algorithm	SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Realistic load models
Nguyen and Gianto (2008)	Stability	Artificial neural network	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Multi-objective task
Carlisle and El Keib (2000)	Feeder voltage profile	Ant bee colony optimization	SSSC, TCSC, UPFC, SVC	IEEE-57 Bus	Practical implementation
Dash et al. (1999)	Small and large power system oscillation	Fuzzy logic	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-37 Bus	Realistic load models
Mazouz and Midoun (2011)	Active power	Fuzzy logic	SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Multi-objective task
Falaghi et al. (2009)	System reliability	Ant bee colony optimization	DG-1, DG-4, SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Realistic load models
Gerbex et al. (0000)	Voltage profile and security	Simulated annealing	PSS, TCSC, SVC	IEEE-37 Bus	Multi-objective task
Abido (2000)	Power system stability	Simulated annealing	PSS, TCSC, SVC	IEEE-9 Bus	Realistic load models
Patjoshi et al. (0000)	Power quality	Fuzzy logic	PSS, TCSC, SVC	IEEE-69 Bus	Multi-objective task
Chen (1996)	Voltage collapse problem	Simulated annealing	SSSC, TCSC, UPFC, SVC	IEEE-57 Bus	Practical implementation
Gitizadeh and Kalanta (2008)	Voltage profile	Simulated annealing	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-37 Bus	Realistic load models
Nair and Nambiar (2002)	Power system damping oscillation	Fuzzy logic	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Multi-objective task
Leung and Chung (1999b)	Reactive power and cost	Genetic algorithm	SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Practical implementation
Surender Reddy et al. (2010)	Voltage stability and cost	Genetic algorithm	PSS, TCSC, SVC	IEEE-37 Bus	Practical implementation
Guo and Li (2009)	Power system oscillation	Particle swarm optimization	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Practical implementation
Khan et al. (2003)	Power system stability	Fuzzy logic	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Practical implementation
Senjyu et al. (1999)	Power system stability	Fuzzy logic	PSS, TCSC, SVC	IEEE-69 Bus	Hybrid techniques
Inkollu and Kota (2016)	Voltage stability	PSO and GSA	DG-3, SSSC, TCSC, UPFC	IEEE-39 Bus	Realistic load models
Shaheen et al. (2008)	Power system security	GA and PSO	SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Practical implementation
Phadke et al. (2012)	Voltage stability	GA and fuzzy logic	DG-1, STATCOM and SVC	IEEE-14 Bus	Multi-objective task
Rashed et al. (2007)	Power transfer capability	GA and PSO	PSS, TCSC, SVC	IEEE-14 Bus	Practical implementation
Bhattacharyya and Gupta (2014a)	Reactive power	GA and fuzzy logic	TCSC, UPFC	IEEE-9 Bus	Practical implementation
Kalyani et al. (2006)	Voltage	Evolutionary computing and sequential quadratic programming	DG-2, SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Practical implementation
Nanda Kumar and Dhanasekaran (2014)	Optimal power flow	PSO and ANN	SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Practical implementation
Alamelu and Kumudhini Devi (2008)	Voltage	Sensitivity analysis and evolutionary programming	DG-4, UPFC, IPFC	IEEE-37 Bus	Hybrid techniques
Ippolito et al. (2006)	Optimal power flow	GA and OPF	SSSC, TCSC, UPFC, SVC	IEEE-300 Bus	Realistic load models
A hybrid Meta-Heuristic (2009)	Reactive power control	TS and PSO	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Multi-objective task
Panda and Padhy (2008)	Power system stability	GA and PSO	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-118 Bus	Practical implementation
Gomez et al. (2004)	Load flow control	ACL and ACO	STATCOM, SSSC, TCSC, UPFC, SVC, GUPFC	IEEE-39 Bus	Realistic load models
Panda (2011)	Power system damping	GA and fuzzy logic	SSSC, TCSC, UPFC, SVC, DPFC	IEEE-9 Bus	Multi-objective task
Khadanga and Satapathy (2015)	Power system damping	GA and GSA	DG-2, HVDC, UPFC	IEEE-14 Bus	Practical implementation
Tayal and Lather (2015)	Small signal oscillation	PSO and fuzzy logic	DG-4, STATCOM	IEEE-14 Bus	Practical implementation
Sadeghzadeh and Ansarian (2006)	Transient stability	ANN and fuzzy logic	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Hybrid techniques
Khazaie et al. (2012)	Sub synchronous reactance and damping	PSO and fuzzy logic	DG-1, STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-69 Bus	Realistic load models
Ma (2007)	Real and reactive power	ANN and fuzzy logic	DG-2, DG-3, STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-37 Bus	Hybrid techniques
Harish Kiran et al. (2016)	Voltage stability	PSO and ABC	SSSC, TCSC, UPFC, SVC	IEEE-300 Bus	Hybrid techniques
Medjber et al. (2016)	Reactive power	ANN and fuzzy logic	SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Realistic load models
Badar and Khan (2016)	Low frequency oscillation	ANN and fuzzy logic	DG-2, STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-118 Bus	Multi-objective task
Khuntia and Panda (2013)	Transient stability	ANN and fuzzy logic	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-39 Bus	Practical implementation
Torabian Esfahani et al. (2015)	Power quality	PSO and fuzzy logic	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-9 Bus	Realistic load models
Wartana and Agustini (2013)	System loadability and active power	PSO and MINLP	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-300 Bus	Multi-objective task
Chansareewittaya and Jirapong (2014)	Power transfer capability	PSO, TS and EP	STATCOM, SSSC, TCSC, UPFC, SVC	IEEE-14 Bus	Practical implementation
Prasad et al. (2012)	Damping of power system	GA and eigen value	DG-3, STATCOM	IEEE-118 Bus	Practical implementation
Albakkar and Malik (2011)	System stability	ANN and fuzzy logic	PSS, TCSC, SVC	IEEE-14 Bus	Practical implementation
Phadke et al. (2009)	Voltage stability	GA and fuzzy logic	PSS, TCSC, SVC	IEEE-69 Bus	Hybrid techniques

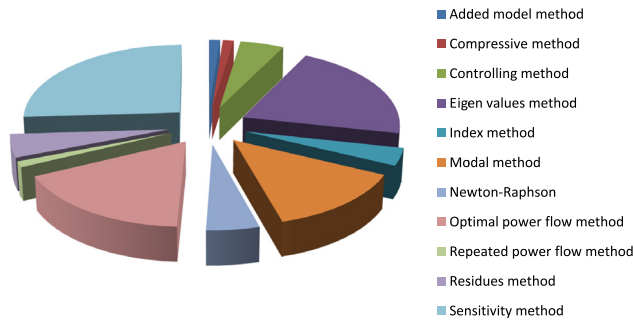


Fig. 1. The conventional methods vs. number of literatures reviewed for impact assessment of optimally placed DGs and FACTS controllers in power systems.

taxonomical format in Section 2 for optimal placement and sizing of DGs and FACTS controllers in power systems from different power system performance viewpoints. The artificial intelligence techniques such as fuzzy logic algorithms, genetic algorithms, artificial neural network algorithms, simulated annealing algorithms, tabu search algorithms, Monte Carlo algorithms, ant bees colony algorithms, modified ant bees colony algorithms, and ant search colony algorithms *etc.* are discussed in taxonomical format in Section 2 for optimal placement and sizing of DGs and FACTS controllers in power systems from different power system performance enhancement viewpoints. The hybrid artificial intelligence techniques that means mixing of any two or more than two above techniques of artificial intelligence techniques or optimization methods or conventional methods.

This paper organized as follows: Section 2-discusses the taxonomical review on optimal placement of DGs and FACTS controllers in the power systems from different power system performance viewpoints. Section 3-introduces the summary of the paper. Section 4-discusses the conclusion and future scope of review work.

2. Taxonomical reviews on impact assessment of optimally placed DGs and FACTS controllers in power systems from different power systems performances viewpoints

The taxonomical review for the impact assessment of optimally placed DGs and FACTS controllers in power systems from different power systems performances viewpoints using different techniques such as conventional techniques, optimization techniques, artificial intelligence techniques and hybrid technique are explained in Table 1.

3. Summary of paper

3.1. Conventional methods

Table 2 and Fig. 1, shows the summary of this article from conventional method for impact assessment of optimally placed DGs and FACTS controllers in power systems.

Fig. 1, it is concluded that the sensitivity analysis (SA), eigen value (EA), modal analysis (MA), optimum power flow (OPF), residue analysis (RA), index analysis (IA), Newton–Raphson (RA), bacterial forging analysis (BFA) and repeated power flow (RPF) are 32%, 26%, 14%, 12%, 6%, 5%, 3%, 1%, 1% respectively. The no. of literatures is reviewed from conventional point of view.



Fig. 2. The optimization methods vs. number of literatures reviewed for impact assessment of optimally placed DGs and FACTS controllers in power systems.

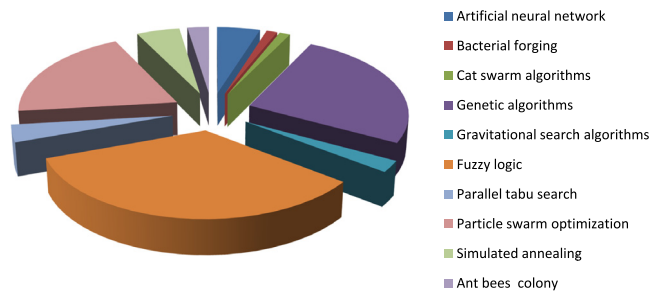


Fig. 3. The artificial intelligence techniques vs. number of literatures reviewed for impact assessment of optimally placed DGs and FACTS controllers in power systems.

3.2. Optimization methods

Table 3 and Fig. 2, shows the summary of this article from optimization method for impact assessment of optimally placed DGs and FACTS controllers in power systems.

Fig. 2, it is concluded that the linear optimization (LO), non-linear optimization (NLO), dynamic optimization (DO), mixed integer optimization (MIO), mixed integer non-linear optimization (MINLO) and integer and mixed integer optimization (IMIO) are 34%, 32%, 18%, 16%, 5%, 4%, respectively. The no. of literatures is reviewed from optimization point of view.

3.3. Artificial intelligence techniques

Table 4 and Fig. 3, shows the summary of this article from artificial intelligence technique for impact assessment of optimally placed DGs and FACTS controllers in power systems.

Fig. 3, it is concluded that the fuzzy logic (FL), genetic algorithm (GA), particle swarm optimization (PSO), artificial intelligence technique (ANN), simulated annealing (SA), parallel tabu search (PTS), ant bee colony (ABC), gravitational search algorithm (GSA), artificial fish swarm optimization (AFSO) and cat swarm optimization (CWO) are 36%, 27%, 18%, 6%, 6%, 5%, 3%, 3%, 2%, 2%, respectively. The no. of literatures is reviewed from artificial intelligence point of view.

3.4. Hybrid intelligence techniques

Table 5 and Fig. 4, shows the summary of this article from hybrid techniques for impact assessment of optimally placed DGs and FACTS controllers in power systems.

Fig. 4, it is concluded that the artificial neural network and fuzzy logic (ANN + FZ), genetic algorithm and fuzzy logic (GA + FZ), genetic algorithm and particle swarm optimization (GA + PSO), particle swarm optimization and fuzzy logic (PSO + FZ), tabu-search and particle swarm optimization (TS + PSO), particle swarm optimization and gravitational search algorithm (PSO + GSA), particle swarm optimization and artificial neural network (PSO + ANN), genetic algorithm and optimal power flow

Table 2

The conventional methods vs. number of literatures reviewed for impact assessment of optimally placed DGs and FACTS controllers in power systems.

Conventional methods	No. of literatures reviewed out of 81	% of literatures reviewed out of 81
Added model method	01	1.23
Compressive method	01	1.23
Controlling method	04	4.94
Eigen values method	17	20.99
Index method	03	3.70
Modal method	11	13.58
Newton–Raphson	04	4.94
Optimal power flow method	14	17.28
Repeated power flow method	01	1.23
Residues method	04	4.94
Sensitivity method	21	25.93

Table 3

The optimization methods vs. number of literatures reviewed for impact assessment of optimally placed DGs and FACTS controllers in power systems.

Optimization methods	No. of literatures reviewed out of 29	% of literatures reviewed out of 29
Dynamic programming	05	17.24
Linear programming method	10	34.48
Non-Linear programming method	10	34.48
Mixed integer non-linear programming method	04	13.79

Table 4

The artificial intelligence techniques vs. number of literatures reviewed for impact assessment of optimally placed DGs and FACTS controllers in power systems.

Artificial intelligence techniques	No. of literatures reviewed out of 82	% of literatures reviewed out of 82
Artificial neural network	04	4.88
Bacterial forging	01	1.22
Cat swarm algorithms	01	1.22
Genetic algorithms	21	25.61
Gravitational search algorithms	02	2.44
Fuzzy logic	28	34.15
Parallel tabu search	03	3.66
Particle swarm optimization	16	19.51
Simulated annealing	04	4.88
Ant bees colony	02	2.44

Table 5

The hybrid intelligence techniques vs. number of literatures reviewed for impact assessment of optimally placed DGs and FACTS controllers in power systems.

Artificial intelligence techniques	No. of literatures reviewed out of 28	% of literatures reviewed out of 28
PSO + GSA	01	3.57
GA + PSO	03	10.71
GA + EV	01	3.57
GA + FZ	04	14.29
EC + SQP	01	3.57
PSO + ANN	01	3.57
SA + EC	01	3.57
GA + OPF	01	3.57
TS + PSO	01	3.57
ACL + ACO	01	3.57
GA + GSA	01	3.57
PSO + FZ	03	10.71
ANN + FZ	06	21.43
PSO + ABC	01	3.57
PSO + MINLP	01	3.57
PSO + TS + EP	01	3.57

(GA + OPF), genetic algorithm and gravitational search algorithm (GA + GSA), particle swarm optimization and ant bee colony (PSO + ABC), particle swarm optimization and mixed integer programming (PSO + MIP), evolutionary computing and sequential quadratic programming (EC + SQP), sensitivity analysis and evolutionary programming (SA + EV), ant colony algorithm and ant colony optimization (ACL + ACO), genetic algorithm and evolutionary programming (GA + EV) are 21%, 14%, 11%, 11%, 7%, 3%, 3%, 3%, 3%, 4%, 4%, 4%, 4%, 4%, 4% respectively no. of literatures are reviewed from hybrid point of view.

4. Conclusions and future scope of the work

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

- The real and reactive power losses should be minimized by optimally placed of DGs and FACTS controllers in power system environments.
- The power quality parameters are also improved by optimally placed DGs and FACTS controllers in power system environments.

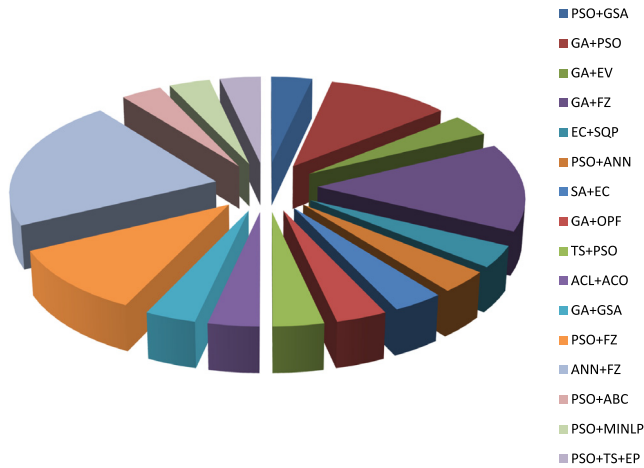


Fig. 4. The hybrid intelligence techniques vs. number of literatures reviewed for impact assessment of optimally placed DGs and FACTS controllers in power systems.

- The cost of electricity also minimized by optimally placed DGs and FACTS controllers in power system environments.
- Other power system performances are also enhanced by optimally placed DGs and FACTS controller in power system environment.

The following future scopes of this work in this direction are as follows:

- In future, the practical systems are implemented with DGs and FACTS controllers.
- In future, the hybrid techniques are used for optimally placed DGs and FACTS controllers.
- In future, multi task objective also adopted for optimally placed DGs and FACTS controllers.
- In future, the dynamic as well as static load modes are used for optimally placed DGs and FACTS controllers.
- In future, various DGs and FACTS controllers can be used in a coordinated manner to enhance the different power system performances.

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