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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.

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 Kodsi and Cãnizares, 2003; Vijayakumar and Kumudinidevi, 0000; Abido, 2009; Kakkar et al., 2010; Narasimha Raju1 et al., 2013; Singh et al., 2010; Singh1 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)

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 Kodsi and Cãnizares, 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; 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 Kodsi and Cãnizares, 2003; Vijayakumar and Kumudinidevi, 0000; Abido, 2009; Kakkar et al., 2010; Narasimha Raju1 et al., 2013; Singh et al., 2010; Singh1 et al., 2014).