ANALYSIS OFDFACTS FOR THE IMPROVEMENT OF PENETRATION CAPACITY

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ABSTRACT

In the last two decades, emerging use of renewable and distributed energy sources in electricity grid has creatednew challenges for the utility regarding the power quality, voltage stabilization and efficient energy utilization.Power electronic converters are extensively utilized to interface the emerging energy systems (without and withenergy storage) and smart buildings with the transmission and distribution systems. Flexible ac transmissionsystems (FACTSs) and voltage-source converters, with smart dynamic controllers, are emerging as a stabilizationand power filtering equipment to improve the power quality. Also, distributed FACTSs play an important role inimproving the power factor, energy utilization, enhancing the power quality, and ensuring efficient energyutilization and energy management in smart grids with renewable energy sources. This paper presents a literaturesurvey of FACTS technology tools and applications for power quality and efficient renewable energysystem utilization.The increasing application and penetration of DG is affecting power flow of the networks and Distributed FACTS (DFACTS) devices, with their capability of power flow control, could be a solution to this issue. In this paper, Monte Carlo simulation is used to simulate the commission and operation of DG in multiple locations. Sensitivity methods are used to select the specific installation location of DFACTS. How DFACTS help to relax restrictions on the location and maximum penetration capacity of DG units is analyzed. Simulation result shows that with the application of DFACTS, limitations of the distributed power's position and capacity can be effectively reduced. This is shown with detailed wind modeling in an example.

1. INTRODUCTION

TRADITIONAL power grids are based on large and centralized power stations connected to high and extra-high voltage networks, which in turn, supply power to medium and then low voltage local distribution systems [1]. However, demands for more and higher quality power, along with the increasing concern about problems related to our environment, such global warming, are placing new challenges to the power grid. Now the grid is more constrained and it is expected to perform better and be "greener". That can be only achieved taking advantage of new technological advances, such distributed generation (DG). DG applications in the vicinity of the load show great operational and power-quality advantages, in addition to transmission losses reduction. They are very appropriate for particular site-specific applications, as they have short period of construction and low investment [2].

When DG is fed into the power grid, it produces changes on the power flow pattern. The natural and renewable power generation coming from wind and sun (photovoltaic) also falls into the DG classification, but they are more variable and can be forecasted only to a limited extent, as they are influenced by complex stochastic meteorological phenomena. Those variations on generation, if not properly accounted for, may bring different challenges, including voltage quality problems, limiting the maximum penetration capacity of DG units on the network and their location.

Choi [3] shows that inclusion of distributed generation in a distribution system would reduce the system losses and hence improves system voltage further when the network is reconfigured. Kashem [4] and Civanlar [5] present different techniques in determining optimal configuration of DG units during normal operating condition. Senjyu [2] proposes an optimal distribution control and coordination with distributed generation and DFACTS (distribution network Flexible AC Transmission System).

In the last years, flexible ac transmission system (FACTS) technologyhas been used in efficient energy utilization, demand control,voltage stabilization, power quality enhancement, power factor correctionand harmonic mitigation [1,2]. Additional applications includepower flow control, voltage regulation, reactive power compensation,transient and steady state voltage stability enhancement, power lossreduction, power conditioning and quality improvement [3,4]. Theemerging use of renewable and distributed generation (DG) has acceleratedand expanded the role of power electronic devices for efficientelectrical utilization and enhanced security and reliability of the electricutility grid [5]. Also, new applications have emerged for standalonemicrogrids with regards to renewable energy utilization usingsolar photovoltaic (PV) systems, micro-hydroelectric systems, the wind,biomass, waste-to-energy and hybrid ac-dc sources with battery energystorage for remote villages [6]. Renewable energy sources (RESs) areutilized at an accelerating rate and connected to both transmission anddistribution/utilization systems using power electronic converters. Thisresults in increased harmonics and deterioration of power quality at thepoint of common coupling. Power quality issues and mitigation haveemerged as serious challenges and issues facing electric utilities andindustrial/commercial/residential users [7].

Various FACTS devices and control strategies can help to mitigatepower quality problems. For efficient use of power system resources theconcept of FACTS was introduced in the late 1980's. The basic conceptof FACTS devices was based upon the use of high-voltage power electronicsto control real and reactive power flow and voltage in thetransmission system [8]Extensive research has focused on new topologies and architecturesof voltage-source converters (VSCs) to improve the performance ofFACTS devices in power systems and consequently enhance powersystem security [9,10]. Recently, FACTS devices and smart controlstrategies have been gaining a more prominent role in energy generationfrom renewable sources such as solar, wind, and waves. Significantresearch has been focused on maximizing the energy extractionfrom RESs. The results of the implementation of FACTS devices in smartgrids with renewable systems are encouraging.The aim of this paper is to review and discuss applications of FACTSdevices in smart grids with RESs. The paper focuses on the followingissues:

- Impact of distributed-FACTS (D-FACTS) systems and emerging voltagesource inverter (VSI) on modern electrical systems stabilization.Power quality harmonic reduction in AC-DC- AC interfacedrenewable energy and battery storage devices.
- Role of FACTS devices and control strategies in electrical powersystem power quality and voltage regulation.
- Comprehensive study of history of application of FACTS devices intraditional and modern electrical networks.
- Different surveys, categorized by the type of published document,top researchers, top research centers and active countries, in termsof FACTS devices technology.

2. OVERVIEW OF POWER QUALITY AND FACTS DEVICES IN ELECTRICALNETWORKS

Power quality issues are manifested as distorted voltage and currentwaveforms and/or frequency deviations that may cause failure or maloperationof customer equipment. Additionally, the power systemsshould provide their customers with a secure, reliable and uninterruptedflow of energy with sinusoidal voltages at the contractedmagnitude level and frequency.

Generally, poor power quality may result in increased power losses,undesirable behavior of equipment, and interference with nearbycommunication lines. Widespread use of power electronics furtherburdens the power systems by generating harmonics in the voltages andcurrents along with increased reactive current.Currently, quality problems have become more complex at all levelsof electrical power systems. Therefore, power quality issues have receivedincreasing attention by both the end users and utilities.

Maintaining the electric power quality within acceptable limits is asignificant challenge. The adverse effects of poor power quality arewell discussed.Various sources use the term power quality indistinctively withdifferent meanings such as supply reliability, current quality, voltagequality, service quality, quality of supply and quality of consumption. Table 1 illustrates the most common problems from the standpointsof consequences, causes and explanation of the power qualityphenomena in power systems. Among these phenomena, voltage sagsaccount for the highest percentage, almost 31%, whereas the lowestpercentage is voltage transients by 8%. Because of the increased use ofsensitive loads, PV systems and power electronic equipment produceharmonic and asymmetrical voltages accounting for 20% and 18%,respectively.

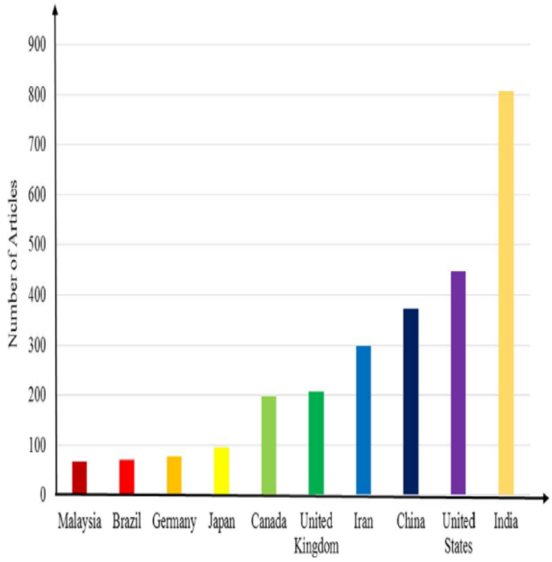

Fig. 3. Number of articles on FACTS devices from1987 to July 2017, sorted by countries.

Over the last three decades, many countries have performed studieson FACTS devices and their application to enhance the power quality intraditional and modern electrical networks. Among them, India rankedthe first, and the United States, China and Iran ranked second to fourthrespectively, as shown in Fig. 1.

3. MODELING AND SIMULATION METHODS

Some DG technologies, such as wind turbines and solar power, are very sensitive to weather variations, therefore their generation output is quite variable and with limited predictability and only partially controllable. Models that account for those features are needed to achieve a better integration of renewable DG technologies; this work is on that line.

A. Modeling of DG

Billinton performs reliability analysis including large-scale wind-farms to find the optimal reinforcement of the network, while using non-sequential montecarlo simulation and some basic wind modeling, Vallee provides some ideas for modeling wind power generation in reliability research.

Given that in the distribution network, the output of DG is generally much lower than 10MW and the characteristics of now typical DG technologies, it is reasonable to use a multi-capacity probability model as given. In this model, stochastic connection and outputvariations are both considered to simulate the contribution of small DG units.

B. The sitting of DFACTS

This paper proposes that by adding some controllability to the transmission capacity of some distribution lines and providing reactive power support to some buses, the restriction on the location and capacity of DG connected to the distribution system could be relaxed.

Monte Carlo simulation is used to try multiple locations and decide the optimal sitting of DFACTS. The flow chart describing this process is given in Fig.2.

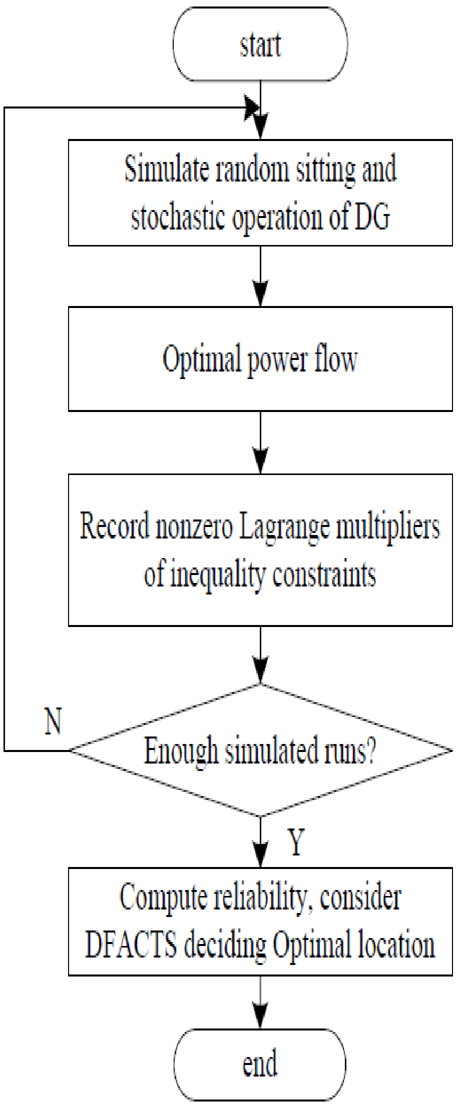

Fig. 2. Flow chart for the optimal sitting of DFACTS.

C. Reliability analysis of distribution system with DGs and DFACTs

After installing DFACTS at some lines and buses, the reliability of distribution network could be improved and at the same time DGs could provide maximum generation. Fig. 3 gives the flow chart for the reliability analysis of distribution system we perform with DGs and DFACTS, when the system is undergoing single or multiple failures.

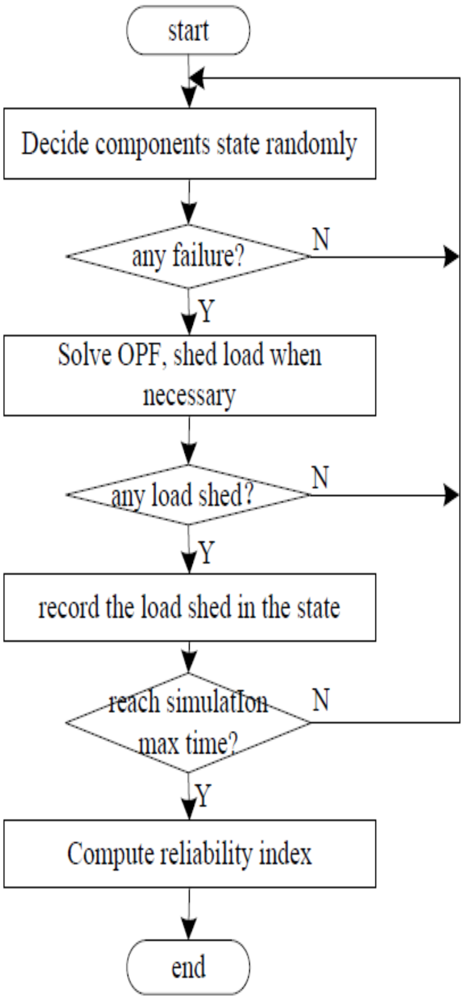

Fig. 3. Flow chart for the reliability analysis of the distribution system.

The reliability computation we perform on the distribution system is aimed to identify whether the power supply to the end users can be ensured.

CONCLUSION & FUTURE WORK

Distributed power technology has proven to be a promising supplement to conventional power systems technologies supplying everyday more demanding consumer requirements. However, these technologies come with new challenges that need to be taken care of. In particular, DGs‟ capacity and location limitations sometime pose restrictions on the potential usage of available renewable resources.

This paper proposes algorithms and simulation procedures to deal with the installation of the DFACTS in the distribution network, allowing better and higher penetration of DGs and the natural resources that sometimes feed them.

We show that limitations on the position and penetration capacity of those DGs can be effectively reduced using DFACTs technologies. This early version of our algorithm is already accounting for one important shortcoming of traditional algorithms reconfiguring DGs (the assumption that they are fully dispatchable). Here we account for the limited availability of DGs associated to renewable resources and because of that the system does not fully count on them during system reconfiguration.

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