MAXIMUM PENETRATION LEVEL FOR INVERTER BASED DISTRIBUTED GENERATION CONSIDERING STABLE OPERATION OF INVERTERS

By

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Title of Thesis:

Maximum Penetration Level For Inverter Based Distributed Generation Considering Stable Operation Of Inverters

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Summary:

The power plants feed loads by power through transmission lines and distribution systems due to large distance between power plants and loads. Nowadays, load demand increases rapidly, this increase requires new plants, transmission lines and distribution systems, which are more expensive. Therefore, distributed generation is used to solve this problem. The installation of inverter based Distributed Generation (DG) has been increasing rapidly in recent years, especially photovoltaic (PV) systems. Such increased penetration will result in decreased short circuit ratio (SCR) which could decrease on the allowable limit that determined by inverter manufacturer. SCR is very important factor for inverter as inverter control depends on this value (SCR must be ≥ specific number) which is determined by inverter manufacturer, if this value becomes (SCR< this specific number): DG will make voltage fluctuations, DG will inject harmonics to power grid and system will become unstable.

In this thesis, the maximum DG penetration level is determined taking into consideration (SCR). This study is considered as a Mixed Integer non linear programming (MINLP) problem where SCR is determined using short circuit calculations .The maximum DG penetration level based on optimal location and DG size is determined using particle swarm optimization (PSO) algorithm and Newton Raphson is applied as a load flow technique. The proposed formulation is tested on IEEE 30 bus system. The results show that the higher penetration levels would be achieved by using the DG decentralized technique.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.
I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

Name: Hesham Ismail Mohamed Mahmoud **Date: November,2018**

Signature:

Dedication

To my family.

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Nomenclature

Abbreviations and Symbols List

DG	Distributed Generation
PSO	Particle Swarm Optimization
$S_{short\ ct}$	Short Circuit Capacity
IEEE	Institute of Electrical and Electronics Engineers
PV	Photovoltaic
SCR	Short Circuit Ratio
P_{losses}	Total lines active power losses
Q_{losses}	Total lines reactive power losses
S	Apparent power

Abstract

The power plants feed loads by power through transmission lines and distribution systems due to large distance between power plants and loads. Nowadays, load demand increases rapidly, this increase requires new plants, transmission lines and distribution systems, which are more expensive. Therefore, distributed generation is used to solve this problem. The installation of inverter based Distributed Generation (DG) has been increasing rapidly in recent years, especially photovoltaic (PV) systems. Such increased penetration will result in decreased short circuit ratio (SCR) which could decrease on the allowable limit that determined by inverter manufacturer. SCR is very important factor for inverter as inverter control depends on this value (SCR must be $\geq$ specific number) which is determined by inverter manufacturer, if this value becomes (SCR< this specific number): DG will make voltage fluctuations, DG will inject harmonics to power grid and system will become unstable.

In this thesis, the maximum DG penetration level is determined taking into consideration (SCR). This study is considered as a Mixed Integer non linear programming (MINLP) problem where SCR is determined using short circuit calculations .The maximum DG penetration level based on optimal location and DG size is determined using particle swarm optimization (PSO) algorithm and Newton Raphson is applied as a load flow technique. The proposed formulation is tested on IEEE 30 bus system.

The results show that the higher penetration levels would be achieved by using the DG decentralized technique.

Chapter 1 : Introduction

1.1. Overview

Generating electricity using fossil fuels has a negative impact on environment, in addition to load demand increases rapidly and distribution facilities have not able to feed this increasing due to technical and financial constraints, so the penetration of renewable distributed generation (DG) in a power system is considered very important. This makes power utilities to decentralize their power systems in order to connect smaller units of renewable DG to the distribution network at or near the load points. The combination between renewable DG and the power system has technical, economic and environmental benefits on the distribution system in addition to the consumers. The renewable DG units' impacts due to this combination on the distribution system have been reported to be increasing in different areas of the world due to environmental impacts of conventional methods of power generation, reliable power demand by the consumers and the development of modern renewable DG technologies [1]. The achievement of these benefits depends on the optimal sizing and location of renewable DG units, type of renewable DG units and **the technology that used to convert the energy** [2].
So in order to achieve the maximum benefits of renewable DG's penetration into a power system, the optimal location and sizing of renewable DG units must be determined. If renewable DG units are not optimally located, this would lead to an increase in power system losses, voltage drop, harmonics and low voltage (LV) stability. This leads to an extra cost of installing additional auxiliaries that will take care of the abnormalities that might have caused conflicting effects on the purpose of using renewable DG units. For these reasons, the power system planners and engineers must apply optimization techniques for determining the optimal location and sizing of renewable DG units [2].

As we mentioned in the above paragraph that achieving the maximum benefits of renewable DG's penetration depends on the technology that used to convert the energy which represented in the inverter that converting DC voltage to AC voltage.

Short Circuit Ratio (SCR) is a very important factor for inverter as inverter control depends on this value (SCR must be $\geq$ specific number) which is determined by the inverter manufacturer.

1.2. Problem Statement

The combination between renewable DG and the power system has many benefits, but it must be properly coordinated e.g. (inverter SCR $\geq$ specific number) which is determined by the inverter manufacturer. Otherwise, the penetration will cause many reverse effects on the existing distribution systems such as: voltage rise, reverse power flow, increasing in power system line losses, and creation of harmonics and deterioration of voltage quality [3].

1.3. Thesis Objectives

- Studying the performance of the meshed distribution system without connecting DG using Newton Raphson load flow technique [4] which calculates the voltage at each bus, total lines active power losses of the system and transmission lines loading to determine which line is overloaded.

- Studying the performance of the meshed distribution system after connecting DG: voltage profile, transmission lines loading and total lines active power losses of the system by using Newton Raphson load flow technique for two approaches. The first approach is the centralized approach which determines the maximum DG capacity that would be installed at a single specific bus and the second approach is the decentralized approach which determines the maximum DG capacity that would be installed at various buses. For two approaches, particle swarm optimization (PSO) is used to maximize the DG penetration level.

- Inverter short circuit ratio (SCR) should be calculated at the bus where DG is connected by calculating the power system short circuit capacity without DG connection divided by DG capacity (Inverter capacity is equal to DG capacity).

- Comparison between centralized and decentralized approaches.

- Different cases of study and their effect on the DG penetration level are presented.

1.4. Thesis outlines

Chapter 1 presents the motivation for this thesis and thesis objectives and thesis outlines.

Chapter 2 presents an overview on DG, types of DG, advantages of DG and stable operation of inverters.

Chapter 3 presents system analysis and problem formulation for maximum penetration level of inverter based distributed generation considering stable operation of inverters.

Chapter 4 presents an overview on optimization techniques especially particle swarm optimization.

Chapter 5 shows the simulation results for different cases of study.

Chapter 6 provides conclusion and offers suggestions for future work.