Chapter 1

Research Motivation and Introduction

1.1 Introduction

In the present power scenario electrical power demand exceeds generation. The demand is steadily increasing because from last few decades onwards the crucial activities such as domestic, municipal, commercial, transportation, agricultural and industrial activities in the society are strongly interconnected with an electrical energy. To meet the capital power burden alternative energy sources such as wind, geothermal, tidal and solar energy sources are considered as suitable alternatives in grid integrated system.

Modern power converters are employed in solar and wind energy sources which have the ability of absorbing or injecting true power (real power) and reactive power (VAR power) into the grid amalgamated systems for enhancing the power quality. At present an electrical power distribution systems consists all most all reactive and non-linear loads (Power Electronic based loads). Due to the gradual increased utilization of non-linear loads the reactive power demand or burden will be more in electrical power distribution systems which increase the feeder losses and subsequently shrinks the real power (P) flow proficiency of electrical distribution networks.

The non-linear loads such as electric arc furnace, electronic gadgets (Computers, Televisions, Monitors etc.,) street lights, digital meters and 1-phase, 3-phase power converters, Adjustable Speed Drive (ASD) and etc., generates substantial asymmetric disturbances in the AC mains may raise Power Quality (PQ) issues like voltage variations, current harmonics, reactive power demand, poor power factor, transients, voltage flickering and etc. in the power system. At present transmission of pure power (pollution free power) to the end consumers is a crucial task for power engineers to acquire effectual and beneficial operation of an electric power system (G. Arnold et al., 2011).
The poor quality of power may lead to overheating, over loading, extra power losses, saturation of transformers, malfunctions of equipment, data errors, quality of services and products and on profits of individual organization and may effect the system’s life time and performance (M. G. Zhang et al., 2014; L.A.Moran et al., 1995).

At the initial stage (1930’s and 1940’s) the passive filters which consists of inductors, capacitors and damping resistors performed an essential role to mitigate the power quality concern in the distribution networks, but due to few remarkable disadvantages of passive filters like their heavy size and weight, poor performance, resonance and execution of constant compensation etc., the power researchers aimed to emerge quick and dynamic solutions to enhance the power quality due to the fast and forward effective movements in the field of Power Electronic devices. Hence the active power filters have been researched and very massive amount of work has been published (K. Palanasamy, Lakshman Naik 2016). So the passive filters are quickly substituted by active power filters. The Fig. 1.1 depicts the classical model of Typical electrical Power System (M.H.J. Bollen et al.,2003).
Fig: 1.1 Classical Model of Typical Electrical Power System (M.H.J. Bollen et al., 2003).

Among the various power filters the shunt APFs are performing a determinant role to mitigate power quality concerns in distribution and transmission systems. The shunt APFs have proved to provide effective and efficient solutions to almost all end consumers load related power quality concerns.

This research work emphases on PV based Statcom as reactive power compensator and active power injector in grid integrated system for enhancement of power quality. The shunt connected device called Static Synchronous Compensator is supplied by PV solar farm hence the name PV-Statcom has been used in this research work. The Photovoltaic solar farm produces only true power during day time and it is entirely in idle position during night time. During night time power feeders have very much lower loads compared to day time. While the wind farm produces large amount of power because of enlarged wind speeds which may result in reverse flow of power from PCC to principal grid source (Rajiv K. Varma et al., 2009), which may causes voltage deviations typically ±5% in the grid tie system. The VSC based shunt APF can balance the active and reactive powers at PCC in order to keep the system voltage within the permissible limits for magnification of power quality in grid integrated test model (Che-Wei Hsu et al., 2011).

This research work represents the active performance of PV-based shunt APF by effective utilization of Proportional Integral controller, Hysteresis Current Controller and P-Q control theory for the attenuation of current harmonics, reactive power compensation, active power injection, power factor improvement, reduction of THD value, voltage sag attenuation as per Low Voltage Ride-Through requirements, voltage regulation at PCC by injecting the current with desired phase and magnitudes.

1.2 Research Motivation

At present the power quality is one of the principal research concerns for all power industries and for all type of commercial activities. An increasing demand for reliable electric power, high quality and increased utilization of non-linear loads may
result in an augmented awareness of high quality power both by utilities and end consumers. The distorting or power electronic based loads are drawing non-sinusoidal currents, so the power pollution has become a severe concern in the distribution and transmission systems. The polluted power will affect not only on the system’s performance but also effects on the productivity and national economy.

Transmission of qualitative power from generating stations to end users is one of the most important major concerns for power researchers, because the presence of reactive and distorting loads in the distribution system.

The non-linear loads (PE based loads) are responsible loads to generate the power quality complications in the power system. Initially the passive filters have been used to attenuate the power quality complications but due to the few remarkable disadvantages of passive filters, these are not able to completely attenuate the power quality problems. The major remarkable disadvantages of passive filters are

- Passive filters are large in size
- Provides poor dynamic performance
- Execution of fixed compensation
- Filtering characteristics are strongly effected by source impedance
- The filtering capacity of the passive filter must be rated by considering both fundamental and harmonic components flowing into the filter
- If the harmonic current component increases the filter will be overloaded
- Creates parallel resonance between passive filter and the power system generates high harmonic currents at the specific frequency.
- It may fall into series resonance with power system and produces excessive harmonic currents.

In order to control these concerns the power researchers are strongly involved in their research work for the development of Power Electronic based active filters for the attenuation of power quality complications in the distribution systems.

Due to the advancements in the field of Power Electronics the active power filters have been researched and enormous amount of work has been published on shunt APF for the attenuation of the current related power quality complications in the distribution systems.
1.3 Problem Statement

Inadequacy of traditional power quality enhancing equipment has necessitated vital and adaptable resolution to power quality concerns. This has impelled the origination of Custom Power Devices. The contemporary and auspicious Custom Power Devices that deals with power quality related issues is Shunt Active Filter. The numerous researches have been accomplished in relation to their performances under a variety of power quality issues with dissimilar traditional linear and non-linear loads. To be regarded as recognized equipment, its performances ought to be scrutinized further with various control strategies for improvement of power quality issues in the distribution systems. This requires the modeling and development of shunt active filter along with its control strategies for power quality improvement in the proposed grid tie system.

The Flexible AC Transmission Systems (FACTS) controllers can enlarge the power transfer capacity of present transmission lines. An innovative research work has been proposed by power engineers on photovoltaic solar farm to utilize as a shunt APFs to magnify the performance of power transmission lines. In this research work the grid integrated PV solar farm inverter is employed as shunt active filter. This method of utilizing photovoltaic solar farm as shunt compensator is known as PV-Statcom. The PV based shunt compensator can absorb or generate the reactive power whose output can be perform satisfactorily, conforming to IEEE laid standards for enhancement of power quality in grid integrated systems.

1.4 Thesis Objectives

The presented objectives are expectantly to be attained in this research work as follows

- To understand the power quality concerns due to enlarged utilization of power electronic based loads.
- To propose the consequences of power quality concerns in the distribution networks.
• To analyze the superior nature of shunt AF and their importance in the modern power system for power quality enhancement.
• To investigate the designing aspects of PV-Statcom for improvement of power quality in the distribution network.
• To apply the various control strategies for generation of reference currents for an initiation of operation of Shunt Active Filters (SAF).
• To evaluate the active power performance of PV based Statcom for
  ▪ Current harmonics attenuation
  ▪ Voltage regulation at PCC
  ▪ Reactive power compensation
  ▪ Active and reactive power injection and absorption
  ▪ Voltage sag mitigation as per LVRT requirements

1.5 Organization of Thesis

Including this chapter the research work thesis is segregated into six chapters. Each individual chapter is differ from the other chapter and is explained with sufficient information to comprehend it.

The second chapter deals with a literature review on power quality issues due to the Power Electronic based loads (distorting) present in the distribution systems. It also briefs about the consequences of power quality issues, various international standards, importance of custom power, especially the superior nature of shunt active filters in the modern power systems. This chapter also briefly describes the various control strategies for generation of reference current signals and different topologies for shunt APFs and applications of Photovoltaic solar farm as PV-Statcom.

The third chapter briefly explains about the steps taken for the realization of PV solar farm as shunt APF (PV-Statcom). The various modes of operation of voltage source converter based PV-Statcom for injection and or absorption of both true and reactive powers for attenuation of power quality complications in the distribution networks are clearly explained with the help of the relevant phasor diagrams. This chapter also gives the detailed reports on the designing aspects of the PV-Statcom. The DC bus voltage, DC capacitor and interfacing inductor are properly designed to get the desired performance of
the shunt APF for magnification of power quality in the proposed grid integrated test model.

The fourth chapter deals with the role of reactive power and its consequences in the power system and implementation of Bang-Bang-Current-Controller for the active operation of PV based active filter to mitigate the current related power quality issues. The MATLAB simulations are carried out to demonstrate the active operation of PV based Statcom for harmonic mitigation, active and reactive power injection and absorption where and when it is needed, for PF improvement and for voltage regulation. The MATLAB Simulink results with designed parameters indicate the improved performance of shunt APF for enhancement of power quality in electrical power systems.

The fifth chapter describes the sources of the voltage sags and its effects on the power systems. The voltage sag is mitigated with the help of LVRT (Low Voltage Ride-Through) requirement. The mathematical modeling of controlled strategy called P-Q control scheme is implemented by Clarke’s transformation technique for the generation of reference current for an initiation of operation of Photovoltaic based synchronous compensator (PV based APF) to magnify the power quality in the distribution systems. The MATLAB simulation outputs indicate the efficient and effective operation of PV based Statcom for extenuation of harmonics and voltage sag by compensating the VAR power (reactive power) in the power system.

The sixth chapter concludes about the research work carried out so far along with some significant future research task has to be carried out to bring out the advancement along the lines of present research work. The references used for this study are also presented.

1.6 Authors Contribution in the Research Work

The major contributions of this research work are

- Various power quality problems and its consequences are clearly analyzed.
- The superior nature of shunt connected PV-Statcom is analyzed along with the study on the different topologies of shunt AF for the magnification of power quality in the distribution systems.
✓ The investigation is carried out for the derivation of “in-phase reference” with the help of calculated Unit Vector Templates method.

✓ The design aspects of various components of shunt AFs are investigated for the extenuation of power quality issues.

✓ An investigation is made on the analysis of instantaneous reactive power theory to activate the operation of Photovoltaic based Statcom for extenuation of voltage sag as per LVRT requirement.

✓ An investigation is carried out on active operation of PV-Statcom towards diminution of current harmonics, reactive power compensation, active and reactive power injection and absorption to regulate the voltage at PCC in the proposed grid integrated Wind-PV systems.