SOLAR PV BASED SHUNT ACTIVE FILTER TO IMPROVE POWER QUALITY USING P-Q THEORY

M.Devika Rani1, T Vijay Muni2, Mohammed Azam3, Dr. Sandeep Gupta4, Aradhana Khillo5, Bibhu Prasad Ganthia5

1Assistant Professor, Electrical & Electronics Engineering, Prasad v Potluri Siddhartha Institute of Technology, Vijayawada, India.
2Department of Electrical and Electronics Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, India.
3Research Scholar, Department of Electronics and Communication Engineering, Shri Jagdishprasad Jhabarmal Tibrewala University, Jhunjhunu, Rajasthan, India.
4Assistant Professor, Electrical Engineering Department, JECRC University, Jaipur, Rajasthan, India.
5Assistant Professor, Department of Electrical Engineering, IGIT Sarang, Dhenkanal, Odisha, India.

ABSTRACT

In modern-day active filters are an excellent means of stabilizing harmonics in industrial facilities. There are many options available but no standard way to rate the active filters. SAPF's basic principles and theoretical concepts describe the filter and circuit design are allude to The PWM filter controller is based on power theory (p-q). A Simulink model was constructed to validate the shunt active filters. Studies have shown that the grid's power quality is verified

Keywords— Photovoltaic (PV) power is added (powered) as an area, passive power (PA), energy yield, and renewable

I. INTRODUCTION

The effects of power quality (PQ) problems are relatively new, but the problems themselves have long been recognised. There have been significant developments in semiconductor technology that have created a revolution in power electronics over the past decade. ASDs that incorporate DC motors, motor drives, and chargers, and adjustable-speed (ASD) drives, account for the increase in problems connected with PQ [2][4]. Non-proportional voltage loads Figure 1 illustrates current distortion. In this circuit, an alternating voltage is applied to a simple resistor whose voltage and current values change as illustrated here although the current is S-shaped, the voltage deviates from that shape

Figure 1.1 Current distortion caused by nonlinear resistance

Non-linear loads appear to cause harmonic distortion in a power network The power generated by nonlinear loads is re-fed back into the system at the common point coupling (PCC). These harmonics can cause a wide variety of problems, mostly capacitors and transformers and motors. The environment is being stressed lately. renewable energy development (RE). due to renewable energy sources such as sunlight, flowing water, and wood These gases are nontoxic and nonrenewable. Malaysia is a sunny country, especially when it comes to solar energy It is generated from photovoltaic (PV) arrays. It is changed into an AC power with an inverter system. to mix the current and PV array together However, a PV array has not been made to use an APF. In any undeveloped country, the power supply always exceeds the demand. Hence, renewable power generation, such as solar and wind, is used to supplement fossil fuel power. Owing to the non-linearity rectified current there are then additional harmonics, but because they cannot be measured, these are called non-harmonic supply currents. This
offers an example of the use of voltage compensation: R + V in parallel (as a shunt) with a voltage multiplier can be used for harmonic and reactive power compensation. The net-inactive filter produces an equal and opposite-amplitude harmonic current to counteract the load current. Here it is listed as either a shunt series or combination shunt, but the shunt is most preferred because of non-linear loads. Non-linear loads, like forces, can be treated as linear. It also serves as a reactive power supply and reduces harmonics.

Fig. 1.2 Principle of shunt APF

Compensating current is provided by the APF, but the loads are non-nonlinear, and as a result, there are no harmonics. The SI are generally used to transform the solar power to distribution system power. But here, the VSI can serve two different functions, that is, energy conversion and reactive power compensation. This is a specific for shunt/brushpolicing in that it uses a P-Q approach in the core element Using this control process, it is just as one would in a shunt filter to control the harmonic loads in the device.

II. LITERATURE SURVEY

Because of the presence of harmonics Thus, the DC load harmonics should be reduced. For harmonic and reactive power reduction, we need to use an APF. In 2011, Chait et al. described the PV modelling and MPPT algorithm in a rapidly fluctuating environment from this simulation, it is seen that the P-V and I-V curves are dependent on temperature and irradiation MPPT offers the greatest efficiency using the MPPT algorithm In this paper (from 2014), Jeevan et al explained that a system which decreases harmonics by generating a current of equal magnitude and opposite phase, and non-reactive with loads such current, but with reactive to the source, that supplies fundamental active currents to nonactive loads. used for both active equalisation and reactive equalisation due to nonlinear loads Since THD in the source was reduced, system performance efficiency was improved. Inverterconverter and non-linear loads create harmonics because of the increased power demand in 2014 Remya found. Additionally, the PV systems are connected to the grid with a three-phase inverter that's multi-device function of providing harmonics reduction. Bouzatia et. al has published a paper showing how they compensated for nonlinear load by using an active filter in 2014 In direct control algorithm (PVSI), the PV array is connected to the source inverter and the grid is connected to the PV system directly with a boost converter. Belaidi et. al described a shunt active filter (SAPF) in which a PV system is connected to a shunt active filter to harmonics suppression and the nonlinear load and reactive power in 2013. the reference Shunt Filters shall be used Synchronous D-Q reference frame (SDF) and carrier-based PWM modulation are used for modulating the voltage source Inverter. was capable of generating current only in multiple frequencies (sinusoidal) with reactive and power compensation. Blan et. al presented a paper in 2012 in which a hybrid three-phase filter (HAPF) is used in tandem with a photovoltaic system. This filter design improves the active filter (APF) performance by using the sliding mode control scheme, while simultaneously filtering out small and wideband harmonics. When this circuit tracks the reference current and source current, the circuit should have a very low THD [15].

III. PV SYSTEM

3.1 Definition
A solar-electricity system makes use of one or more solar panels to do the job There are complex and variable (i.e.e. modular) components (and features that work together), all of which consist of photovoltaic modules, as well as mounting and attachment structures.

3.2 Photovoltaic Arrangements
3.2.1 Photovoltaic Cell PV cells are constructed from semiconductor materials such as silicon. By means of a semiconductor treatments, thin wafers are engineered to create an electric fields of different polarities (either
positive or negative) on the front and back sides. As light energy is applied to the solar cell, the electrons are released from the atoms in the semiconductor. Electrical conductors are connected to the positive and negative sides to form an electrical circuits, and serve as a means of containing the electrons, allowing them to be captured as electric current. Once this energy is put to a load, it can be used for additional purposes. The PV cell can be made in either a circular or a square format.

![Figure 3.1 Basic Structure of PV Cell](image1)

### 3.2.2 Photovoltaic Module
For higher voltage, several series-connected PV cells are connected together (generate more than 0.5V). A sepsis may be needed to keep out in, if only the back side is shaded, or total. The reverse currents of mono-stabilised silicon may be sufficient, and these are not required. Could also cause damage shaded cells solar cells become less efficient when hotter.

### 3.2.3 Photovoltaic Array
The power one module can produce is insufficient for the home or business. The majority of PV systems use an inverter to generate AC current that can power other devices. To obtain desired voltages, modules are usually connected in series; to allow the system to operate more efficiently, individual modules are connected in parallel.

![Figure 3.2 Photovoltaic system [16]](image2)

### IV. SHUNT ACTIVE POWER FILTER
Power quality issues have arisen in the recent years of late-generation development. Many industrial-use power converters are used in the household, too. The power converters' input currents are highly nonlinear. A wide range of frequencies, which include: fundamental, third, seventh, twelfth, and higher-harmonic, are drawn by power converters. The problem is that these voltage levels are even more problematic in AC lines. To meet the desired performance threshold, a passive power filters have been used. Most common loads are unbalanced three-phase and single-phase loads.

This whole chapter mainly describes how to model and examine the reactivity of shunt filter for compensation. A variety of design considerations, such as power, control, are covered in this research project. This is the three-phase load distribution scheme in fig. 4.1.
4.1 Basic compensation principle of STATCOM

A STATCOM's power distribution system (especially those without losses can be compared to a transmission STATCOM) shares a similar architecture. These specific and additional harmonics are balanced with the injector filters by injecting the exact and opposite harmonics. In this case, the harmonics of the active power filter are no longer reduced by active circuitry but increased by a current flow through the shunt. Expanded explanation: Fig. 4 depicts the working power supply link.

The compensation principle shown in fig. 4.4. a voltage shunt is used as the active power filter. This active power filter is made so as to draw or to supply current in opposition to or with an even flow, which it cancels out on the AC side nonlinearity, i.e. it cancels the AC current. For example, in figure 5.5, the load current is shown, with respect to frequency, the compensating current that contains all of the harmonics is also. It is the primary goal of a shunt filter to cancel harmonics and to compensate for reactive power.
V. GRID CONNECTED PV SYSTEM WITH ACTIVE POWER FILTER

The bi directional converter with six-switches having the combination of both switching and filter component Type of this power filter is dependent on VSI having a capacitor for the DC supply and non-linear load for DC rectification, with an inverter attached. In anti-parallel with each diode is connected to allow current flow. For reactive power compensation, the APF interconnected shunts (distributes) reactive power to a distribution line at PCC and also eliminates non-linear loads. This nonlinear load is being loads are connected in shunt. This active filter has the capability of identifying harmonic currents and equalising those currents by injecting a compensating current. As a result, the current flows as a fundamental frequency sine waveform.

\[ p-q \] theory Based Control
Akagi et al in 1983 introduced P-Q theory, which is known as “immediate activeness” This can be done by doing the α-β transformation

![Fig.5.2 Block diagram of p-q compensation theory](image)

P-Q theory can be achieved by transforming the voltage and load current into α-β co-ordinates as following

\[
\begin{bmatrix}
V_α \\
V_β 
\end{bmatrix} = \sqrt{2/3} \begin{bmatrix}
1 & -1/2 & -1/2 \\
0 & \sqrt{3}/2 & -\sqrt{3}/2 
\end{bmatrix} \begin{bmatrix}
V_a \\
V_b \\
V_c 
\end{bmatrix}
\]

\[
\begin{bmatrix}
i_{LA} \\
i_{LB} 
\end{bmatrix} = \sqrt{2/3} \begin{bmatrix}
1 & -1/2 & -1/2 \\
0 & \sqrt{3}/2 & -\sqrt{3}/2 
\end{bmatrix} \begin{bmatrix}
i_{La} \\
i_{Lb} \\
i_{Lc} 
\end{bmatrix}
\]

The instantaneous active power \(pL\) and reactive power \(qL\) can be expressed as

\[
\begin{bmatrix}
pL \\
qL 
\end{bmatrix} = \begin{bmatrix}
V_α & V_β \\
V_β & -V_α 
\end{bmatrix} \begin{bmatrix}
i_{LA} \\
i_{LB} 
\end{bmatrix}
\]

These \(pL\) and \(qL\) power can be divided into oscillatory and average terms as following

\[pL = \overline{p} + p\]

\[qL = \overline{q} + q\]

where,

\(\overline{p}\) = The immediate deployment of enormous real power Transferring a load-normalized voltage mean and treated as a voltage mean such that they both appear in the destination

\(p\) = In this case, instant power only exists where there is no value, but must be paid for; thus, it is treated as an add and removed (value created on one end and lost on the other).

\(\overline{q}\) = Instantaneous imaginary power is incompatible with AC. Because of this, it causes undesired current, it must be compensated.

\(q\) = immediate imaginary power should be measured in terms or else it is the same as compensating for conventional power that has been produced using the APF

It is estimated that in p-q theory that the amplitudes of the original supply voltages are sinusoidal, and power calculation is done by making use of these sinusoidal voltages.
The powers that have to be compensated are described as below
\[ p_c = p + p_{loss} \]
\[ q_c = -q_L \]

where,
\[ p_{loss} = \text{required active power for a device to offset DC connection voltage/required power to compensate for device loss} \]

We have used the transposing matrix, we end up with the compensating reference currents which appear as follows
\[
\begin{bmatrix}
    i_{ca} \\
    i_{cb}
\end{bmatrix} = \frac{1}{V_{\alpha}^2 + V_{\beta}^2} \begin{bmatrix}
    V_{\alpha} & V_{\beta} \\
    -V_{\alpha} & -V_{\beta}
\end{bmatrix} \begin{bmatrix}
    -p + p_{loss} \\
    -q_L
\end{bmatrix}
\]

To expand the dynamic range of a the hpf (dynamic range, lpf) and expand the response by using feed-forward.

Another vital component is the dc connection voltage regulator, which compensates both for small instantaneous errors in voltage and provides rapid responding.

Therefore, the differential error voltage must be added to dc-resistance.

1. Simulation Results

6.1 Conventional Simulation Circuit

Fig 6.1 Conventional Simulation Circuit
Fig 6.2 VSC with Filter

Fig 6.3 Grid Current, Load Current, Filter Current

Fig 6.4 Three phase Grid Current, Load Current, Filter Current
Proposed Simulation Circuit
VI. CONCLUSION

Based on simulations, the paper applies the P-Q theory to the problem. The harmonic compensation in the load is achieved by reshaping the source so as to resemble a sine wave. The active and reactive power graphs are shown after and before the filter is activated.
REFERENCES


