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Power Quality Improvement in PV Grid Connected System by Using Active Filter: Review

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ABSTRACT:This paper present review a power quality problems a raised by changes in weather conditions like solar radiations and the variation in the load connected with the system. These power quality problems like voltage fluctuation, voltage distortion, and harmonics at the L.T. line are generated by source and load also at the PCC. In this paper present review of Power quality problems and mitigation technique on the by using active filters.

KEYWORDS: Active filter, Control strategy, grid connected PV system, power quality issues.

I.INTRODUCTION

Age of fossil fuel as source of energy is constantly getting extinct. Demand of fuel and energy is exponentially rising with time. At the same time energy cost is also continuously increasing. To overcome these critical situations we can use renewable resources at our disposal from which energy can be tapped. Photovoltaic cells converts solar energy to direct electric energy. The advantages of solar energy are:

1. It requires less time to install and start up new unit for generation.
2. It has no rotating parts, hence no noise, no maintenance and long life with less maintenance.
3. Solar energy is abundantly available on earth.
4. Problem of low efficiency and higher initial cost can be overcome by advance technology solar PV panel.
5. This energy source is non-polluting and available continuously free of cost.[10]

It is anticipated that Photovoltaic system will be major source of energy fulfilling global energy needs.

The application of PV systems in power systems can be divided into two main fields: off-grid or stand-alone applications and on-grid or grid-connected applications. Stand-alone PV systems can be used to provide power for remote loads that do not have any access to power grids while grid-connected applications are used to provide energy for local loads and for the exchange power with utility grids. [1]

Photovoltaic system has been increasingly used in medium sized grid with domestic utilities. PV panels are connected in series and parallel to generate usable amount of voltage and current. By series connection voltage level can be built up and by parallel connection current density can be increased. In addition to that Converter configuration should be efficient and cost effective.

PV systems can enhance the operation of power systems by improving the voltage profile and by reducing the energy losses of distribution feeders, the maintenance costs, and the loading of transformer tap changers during peak hours [2]. In comparison with other renewable technologies, PV systems still face major difficulties and may pose some adverse effects to the system, such as overloading of the feeders, harmonic pollution, high investment cost, low efficiency, and low reliability, which hinder their widespread use [3]. Moreover, variations in solar irradiation can cause power fluctuation and voltage flicker, resulting in undesirable effects on high penetrated PV systems in the power system [4]. Some control methods, such as Maximum Power Point Tracking (MPPT) can be used to improve efficiency of PV systems. In such controllers, both the produced voltage and the current of the PV array should be controlled. This may complicate the PV system structure with increased possibility of failure while tracking maximum power in unexpected weather conditions [5]. the PV system-based distributed generations (DGs) may energize the local loads after the system has been disconnected from the utility grid during faulty conditions [6]. In these situations, any unintentional

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islanding may increase the risk of safety problems or damage to other parts of the system components, which can decrease system reliability [7].

Solar PV system connected at distribution level is termed as distributed generation (DG). The utility is concerned due to the high penetration level of PV system in distribution systems as it may cause to affect stability, voltage regulation and power-quality (PQ) issues. However, the excess use of power electronics based equipment and non-linear loads at PCC generate harmonic currents, which may affect the quality of power. This creates unbalancing effect on transmission and generation side and also load current harmonics may result in voltage harmonics and can create a serious PQ problem in the power system network. Active power filters (APF) are easily used to compensate the load current harmonics and load unbalance at distribution level. The connection topologies of filtering into the system to overcome the PQ problems are also discussed.

For Harmonic mitigation passive filters were used traditionally, but due to certain drawbacks of resonance due to matching with line impedance, can compensate single harmonic at a time, bulky in weight they are not much in use. With development of semiconductor devices active harmonic filters with different current control strategies are extensively used. Shunt Active filter can be formed from topologies like CSI, VSI.. There are many current control methods used in active filters. Hysteresis current control method, synchronous reference frame, direct control method, fuzzy logic, dead beat control are used for PWM generation.

This paper deals with a the PQ problems related to solar connected to the grid and the impact of poor power quality and to study the effects of different weather conditions grid-connected PV systems on the dynamic operation

II.LITERATURE SURVEY

Prakash K Ray, Soumya R Mohanty presents a power quality issues in distributed generation system by environmental changes and also change in load. The solar irradiance or insolation forms a voltage sag and swell system. Author are also mention mathematical approach by a techniques such as modular probabilistic neutral network (MPNN), support vector machine (SVMs) and least square support vector machine (LS-SVMs) to classify PQ disturbances, S-transform has the advantage of better time Freq. resolution and its capability of detection and localization of disturbance even under noisy condition [8]. John H.R.Enstin,& Peter J.M.H eskes was discuss and analyse phenomenon of harmonic interference of P.V. inverters and to compare the network, interaction of different inverter function and controls. They investigated power quality problems and also try to find out harmonics pollution regarding series and parallel resonance in distribution network. The simulate the experimental model with laboratory experimental as well as computer modelling of different inverter topologies and summaries it with redesigning with (inverter) outer filters[9]. Minas Patsalides, Demetres Evagorou1, George Makrides was present analysis on effect of solar irradiance on power quality. They studied the low irradiance lead to undesirable variation of power and in supply quality of voltage and current and this variation proves the low solar irradiance has a significant impacts on the power quality of the output of the pv system [11].M. J. E. Alam,K. M. Muttaqi, and D. Sutanto are provides an overview of some of the known PQ issues related to the introduction of different types of DG systems into a power network. The analysis is based on common types of DG system designs and associated technologies.Common PQ problems arising from DG systems impacting on power network as well as common existing network based PQ issues impacting on DG systems have been identified [12]. Walid A. Omran, M. Kazerani are present a investigation of method for reduction of power fluctuation generated from large grid connected pv system. These fluctuations are happened due to change in irradiation level. This effect are creates fluctuation in power generation. So they focus on investigation method as 1) Use battery storage system,2) use of dump load, 3)curtailment of the generated power by operating the power conditioning unit of the PV system below maximum power point [13]. AchimWoyte, Vu Van Thong are explain the voltage fluctuation happened due to moderate climate characterized. These fluctuations are short time nature. This is mainly happened on low voltage grid/ rural grid. In this study, severity of grid voltage and power flow fluctuation at the point of common coupling as a consequence of fluctuation in solar irradiance. Due to clouds moving over the area. They described specific description of fluctuation has proposed by three parameters – magnitude, duration of transition between clear and cloudy, & speed of the transition, and ratio of magnitude & duration [14].Dr.SavitaNema, Dr.Prashantbaredar present analysis network behaviour with increasing level of rooftop solar PV penetration into low voltage network. This paper also propose a three phase power flow approach and power flow calculation have been performed using the proposed approach to investigate the impact of single phase variable PV generation. In which PV generation are affected by the solar irradiation and voltage, current rise are rises in system during midday [15].

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On the basis of literature survey we trying to find out the power quality problems arises due instant solar irradiation fluctuation and due to load fluctuation during this time.

III.SYSTEM DEVELOPMENT

For the synchronization of utility grid and grid connected PV system, some condition has to satisfy like voltage level, frequency and phase sequence matching. This synchronization is done by PV inverter which having advance power electronics technology.
The power-voltage relationship or current-voltage relationship of the cell can generally be representing the Electrical characteristics of a PV unit. The changes of solar irradiance on the cell and the cell temperature are directly varies these characteristics. A proper simulation model is needed to convert the changes of temperature and radiation on generated voltage and current of the PV arrays. So that at the different weather conditions, the dynamic performance of PV system can be analyse.

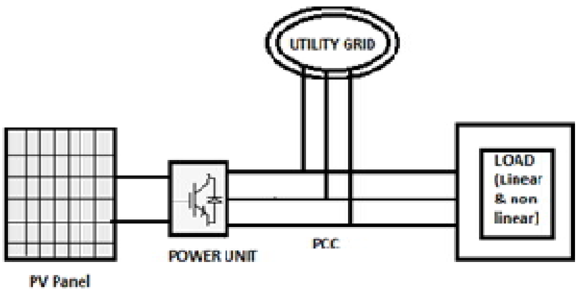

Fig. 1 Grid connected PV system

Solar cell is basically a photovoltaic cell form of p-n junction. It when exposed to sunlight absorbs some energy greater than band-gap. This creates some hole-electron pairs proportional to incident radiations. These carriers are affected by internal electric fields of p-n junction and forms photo current proportional to solar insolation. PV cells have nonlinear characteristics which vary with radiation intensity and temperature.

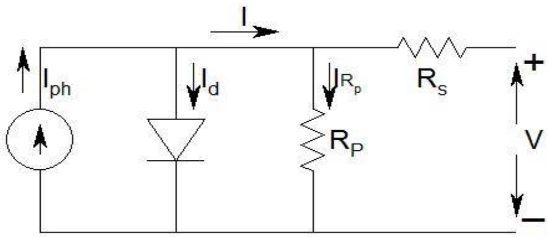

Fig. 2 Equivalent circuit Diagram of PV cell

PV cells produces less than 3W at 0.5 to 0.6 Volts, so cells are connected in series to produce enough power. The terminal equation for the current and voltage of the array of PV panels are given as under(fig 2):

$$I = I_P - I_D - I_p = 0 \quad (1)$$

$$V = V_D - R_S I \quad (2)$$

$$I_P = \frac{V_{PV} + R_S I}{R_P} \quad (3)$$

$$I_D = I_O(e^{\frac{q(V+R_S I)}{NkT}} - 1) \quad (4)$$

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I_{Ph}= Light Generated Current
V= Terminal Voltage Of The Cell
I_d = Diode Current
I_o = Saturation Current
I_P = Shunt Current
q = Electron Charge
k = Boltzmann Constant
T =Temperature
R_D = Series Resistance
R_P = Shunt Resistance

Boost Converter and Inverter:
Boost converter increases voltage level for inverter and control MPPT. Output voltage of boost converter is higher than input voltage. Input current is same as inductor current and hence it is not discontinuous as buck convertor and hence input filter requirements are relaxed in boost convertor. If solar panels of high rating are implemented then requirement of boost converter can also be relaxed and switching loss in converter can be saved.
PV Panels generate DC Voltage and to connect panels to grid DC power has to be converted to AC Power. We require inverter to convert DC to sinusoidal AC before connecting to grid. Output voltage and frequency should be same as that of grid voltage and frequency. Many inverter topologies are available. In proposed scheme PWM (pulse width modulated) Voltage Source Inverter is selected d-q theory with phase. Output of the Inverter is near to Sinusoidal. 6 switches are used and its switching is controlled by discrete PWM signals. Electrical diagram for inverter is shown in Fig. 3.

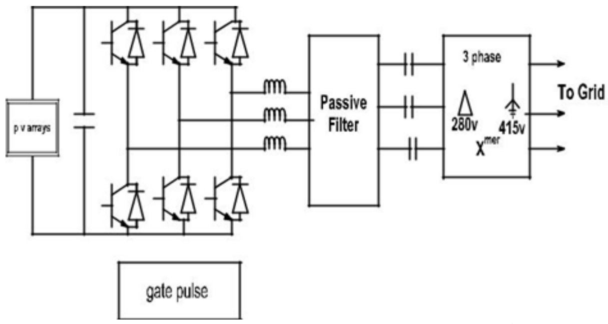

Fig.3 PWM 3 phase inverter with passive filter

3.1 Possible Effects on Distribution System Due to Grid Connected PV System:

In the renewable energy system, PV system is more reliable sources of energy. So that it attracting considerable commercial interest. For distribution network, the connection of distributed PV system to utility grid may causes several operational problems. The severity of these problems distinguishes on the basis of the percentage of PV penetration and the geography of the installation. So that, knowing the possible impact of distributed grid-connected PV systems on distribution networks can provide feasible solutions before real-time and practical implementations. This section is for the introduction to possible effects which PV system may causes on distributed system.
A. Over voltage
PV systems are designed in that way so it can fully utilize solar energy. It is happened only when system is operating near unity power factor. In this case, the reactive power flow of the system may changes due to active power from PV system injects into utility grid. Hence, due to the lack of reactive power, voltage of near buses can be increased.[9]. The produced over-voltage can have negative effects on the operation of both the utility and customer sides.

B. Harmonics
Harmonic distortion is a serious power quality problem that due to use power electronics devices in PV system like power inverter that convert DC power into AC power. Due to inverter, the produced harmonics can cause series and parallel resonances, overheating in transformer and capacitor bank, and reliability of power systems may reduce due to false operation of protection devices, inverter and pwm generator [12].

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C. Power Fluctuation

The fluctuation of the output power of PV systems is one of the main factors that may cause severe operational problems for the utility network. The variation in solar irradiance occurs due to the movement of clouds and may continue for minutes or hours, depending on wind speed, the type and size of passing clouds, the area covered by the PV system. These variations in solar irradiation causes for power fluctuation. And this Power fluctuation may cause for unacceptable voltage fluctuation, voltage flickers, power swings in lines, and over- and under loadings [10].

D. Frequency fluctuation

Frequency is most important factor in power quality. Frequency fluctuation may causes due to imbalance between the consumed and the produced power. The small size of PV systems causes the frequency fluctuation to be negligible compared with other renewable energy-based resources. However, increasing the penetration levels and no. of distributed PV systems becomes more severe for these issues.

E. Inrush Current

The difference between grid voltage and PV system voltage may introduce an inrush current that flows between the PV system and the utility grid at the time of connection, and an exponentially decays to zero. Nuisance trips, thermal stress, and other problems may causes due to the inrush current [13].

These problems are occurs due to changes in grid connected PV systems. These problems can be eliminated. Harmonics, over voltage due to excess reactive power in the grid, voltage fluctuation by traditional methods like passive filters. But in traditional method or passive filter have fix range to eliminate the problems. The inductors, capacitors value are fix. Because of that it can work for fix range of harmonics. It doesn't work for reactive power. It can't inject excess voltage in the system or draw excess voltage from the system during Voltage fluctuation. If value of inductance and capacitor will increased, the impedance of the grid may be changes. So it causes other problems. So that active filter is way to improve power quality by eliminating these problems. It covers many problems with the system from generating as well as load of system.

IV. ACTIVE FILTERS

Harmonics, reactive power, fluctuation and/or neutral current in ac networks is being compensated by the Active filter technology. It has been transformed in the last 25 with development of various configurations, power electronics/ switching devices and control strategies. AF's are also used to improve voltage balance, regulate terminal voltage, eliminate voltage harmonics and suppress voltage flicker in three-phase systems. These issues are achieved by combination or individually. But it is depending upon the configuration, control strategy or requirements which have to be select properly. This section presents the development and current status of active filter. Large numbers of publications are presents work regarding the power quality survey, measurements, analysis, cause, and effects of harmonics and reactive power in the electric networks [15]—[20].

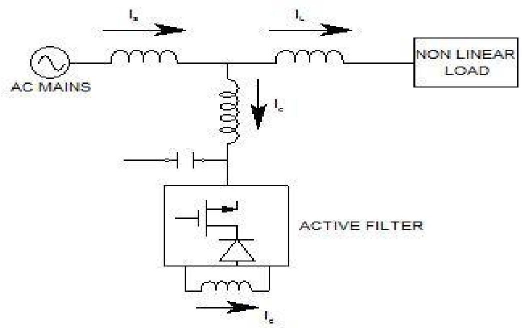

Fig.4 Current-fed-type Active Filter

Active filters are classified on the basis of converter type, tropology, and number of phases. And the converter on the CSI or VSI bridge structure. The topologies are shunt, series, or a combination of both. The third is based on the number of phases, like two-wire (single phase) and three- or four-wire three-phase system.

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Active filter have two type of converter. Fig. 4 shows the current-fed (PWM) inverter structure. It behaves as a non-sinusoidal current source to meet the harmonic current requirement of the nonlinear load. This converter is to be considered sufficiently reliable but It has higher losses and require higher values of parallel ac power capacitor [35], [39]. For the better performance in higher rating, multilevel mode cannot be used by this converter. Fig. 5 shows the voltage-fed PWM inverter structure. It has a large dc capacitor which supports dc voltage bus. It is lighter, cheaper and multilevel and multistep. Multilevel improve the performance with lower switching frequency.
AF's can be classified based on the topology used as series or shunt filters [22], [23], [51], [52], [55], Fig. 5 shows an shunt active filter, it eliminates current harmonics, reactive power compensation and balancing balanced current. A nonlinear load injects current harmonics.so it is mainly used at the load end. It injects equal compensating currents, opposite in phase, to cancel harmonics and/or reactive components of the nonlinear load current at the point of connection. For stabilizing and improving the voltage profile, it can be used as a static var generator in the power system network. Fig. 5 shows a stand-alone active series filter. It is connected before the load in series with the mains, using a matching transformer. It can reduces negative-sequence voltage and regulate the voltage on three-phase systems [51], [52], it can eliminate voltage harmonics [22], and to balance and regulate the terminal voltage of the load or line.

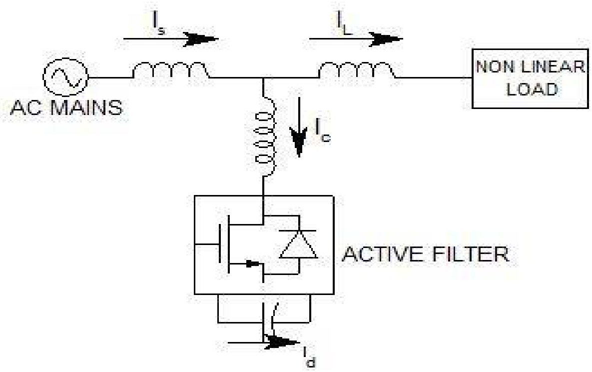

Fig. 5 Voltage-fed-type Active Filter.

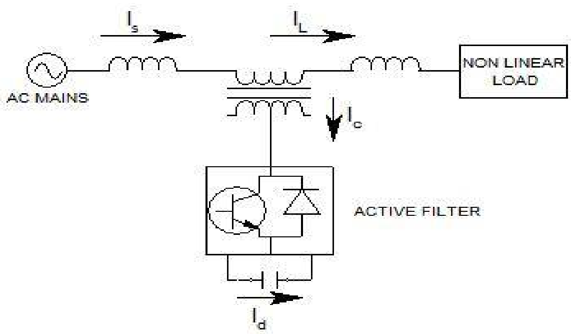

Fig. 6 Series-type Active Filter.

ASD's are major applications of power electronics converter, and many three phase three wire nonlinear loads are incorporating active filters in their front-end design. Different types of configuration had appeared on three wire shunt/series active filter by a large numbers of publications [1]-[20]. In three-wire active filters, all the configurations are developed with three wires on the ac side and two wires on the dc side. The current-fed type (Fig. 4) or voltage- fed type with single-stage (Fig. 5) or multistep/multilevel [33], [34], [43], [44] configurations are developed in shunt active filter. Active shunt AF's are also designed with three single-phase AF's with isolation transformers for proper voltage matching, independent phase control, and reliable compensation with unbalanced systems.

SELECTION OF COMPONENTS AND ADDITIONAL FEATURES OF ACTIVE FILTER

For the better performance of active filters, selection of their components is an important factor. The main component of the active filter is power electronics devices. In the earlier days, BJT's take over by MOSFT's were used in small rating. Nowadays, the IGBT is mostly used to medium rating and GTO's are used to higher rating. A series inductor (L_c) at the input of a VSI bridge is normally used as the buffer between supply terminal voltage and PWM voltage generated by the Active filter. This value of this inductor is very important factor in the performance of the Active Filter. If a small value of L_c is selected, then large switching ripples are injected into the supply currents, and a large value of L_c does not allow proper tracking of the compensating currents close to the desired values. An optimum selection of L_c is essential to obtain satisfactory performance of the active filter. A passive ripple filter is used at the terminal of the supply system, which compensates for switching harmonics and improves the THD of the supply voltage and current. And another important part is the design of the passive ripple filter, because source impedance can cause an interaction with its components. Another important parameter is the value of dc-bus capacitor C_{dc} of the active filter. A small value of C_{dc} shows large ripples in the steady state and wide fluctuations in the dc-bus voltage under transient conditions. A higher value of C_{dc} reduces fluctuations and ripples in the dc-bus voltage, but it increases the cost and size of the system. In general, active filter are mostly used to compensate current and voltage harmonics, but they also have additional features, such as compensation for reactive power, current and voltage unbalance, neutral current, voltage flicker, voltage spikes, and for voltage regulation. Most of the current-related compensations like as

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reactive power, current unbalance, etc. are carried out using shunt active filter, while voltage related compensations like as voltage unbalance, regulation, flicker, etc. are made using series active filter. Sometimes, the structure similar to active filter is used exclusively for additional features, such as reactive power compensation, load balancing, voltage regulation and voltage unbalance compensation, etc.

CONTROL STRATEGIES

The heart of the Active filter is Control strategy and it is implemented in three stages. In the first stage, the essential voltage and current signals are sensed using power transformers (PT's), CT's, Hall-effect sensors, and isolation amplifiers to collect accurate system information. In the second stage, compensating signals in terms of current or voltage levels are derived based on control methods and active filter configurations. In the third stage of control, the gating signals for the power electronic devices of the active filter are generated using PWM, hysteresis, sliding-mode, or fuzzy-logic, instantaneous power theory based control techniques. The control of the active filter is using discrete analog and digital devices, microprocessor or microcontroller etc.

A. Signal Conditioning

Several instantaneous voltage and current signals are required for the purpose of implementation of the control algorithm. These signals are used to monitor, measure, and record various performance indexes, such as total harmonic distortion (THD), power factor, active and reactive power, crest factor, etc. The typical voltage signals are AC terminal voltages, dc bus voltage of the active filter and voltages across series elements. The current signals to be sensed are load currents, supply currents, compensating currents, and dc link current of the active filter. Voltage signals are sensed by using PT's or Hall Effect voltage sensors or isolation amplifiers. Current signals are sensed by using CT's or Hall-effect current sensors. The voltage and current signals are filtered to avoid noise problems. The filters are either analog based or digital based with low pass, high pass, or band pass characteristics.

B. Derivation of Compensating Signals

Compensating signals are developed either in signal of voltages or currents. this compensating signal is an important part of active filter control and affects their rating and transient, as well as steady-state performance. Compensation techniques are based on frequency-domain or time-domain correction techniques.

1) *Compensation in Frequency Domain*: Control strategy in the frequency domain is based on the Fourier analysis of the distorted voltage or current signals to extract compensating signals [24], [27], [30], [32], [38], [41],[47]. The compensating harmonic components are separated from the harmonic-polluted signals by using the Fourier transformation and combined to generate compensating signals. The device switching frequency of the active filter is kept generally more than twice the highest compensating harmonic frequency for effective compensation. The on-line application of Fourier transform (solution of a set of nonlinear equations) is a cumbersome computation and results in a large response time.

2) *Compensation in Time Domain*: Control methods in the time domain are based on instantaneous derivation of compensating signals in the term of either voltage or current signals from distorted and harmonic-polluted voltage or current signals. There is numbers of control methods in the time domain, which are known as instantaneous "p-q" theory [31], [33], [34], [39], [43], [44], [45], [46], synchronous d-q reference frame method [18], synchronous detection method [56], flux-based controller [54], P-I controller [25], sliding- mode controller [25], [50], [53], [54], etc.

The instantaneous active and reactive power (p-q) theory is based on "a-/3" transformation of voltage and current signals to derive compensating signals. The instantaneous active and reactive power is computed in form of transformed voltage and current signals. Harmonic active and reactive powers are extracted using low-pass and high-pass filters from instantaneous active and reactive powers. Compensating signals in forms of either currents or voltages are derived using reverse "a/3" transformation, from harmonic active and reactive powers. In the synchronous d-q reference frame and flux-based controllers, voltage and current signals are transformed to a synchronously rotating frame. These fundamental quantities become dc quantities. After that the harmonic compensating signals are extracted. The dc-bus voltage feedback is mostly used to get a self-supporting dc bus in voltage fed Active filter. In P-I and sliding-mode controllers, dc-bus voltage in a VSI or dc-bus current in a CSI is maintained to the constant value and reference values for the magnitudes of the supply currents are obtained. Compensating signals are derived by subtracting load currents from reference supply currents.

C. *Generation of Gate Signals for Converter*

The third stage to generate gate signals for the power electronic devices of the active filter based on the derived compensating signals in term of voltage or current. Different types of approaches like as hysteresis-based current control, PWM current or voltage control, deadbeat control, sliding mode of current control, fuzzy-based current control,

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etc., are implemented either through hardware or software in DSP-based designs to obtain the control signals for the switching devices of the Active filter.

SELECTION CONSIDERATIONS OF AF's FOR SPECIFIC APPLICATIONS

Selection of the active filter for a specific application is an important task for end users and application engineers. There are mostly application requires single-phase or three-phase, three-wire and four wire systems with requiring current or voltage-based compensation. There are a number of active filter configurations which may match with the needs of individual users. A brief list of criteria for selection of an appropriate active filter for a specific application is discussed in this section. Table 1 show a summary of selection of suitable active filters for specific users.

A. Current-Based Compensation

Current harmonics compensation, reactive power compensation, load balancing, and neutral current compensation are compensated on the basis of Current based compensation. This compensation may either be required individually or in a combination by the individual users. For the current harmonics compensation, the active shunt filter is an ideal device. Reactive power compensation is carried out by using active shunt filters for adjustable loads and by using dc capacitors for fixed load. Load balancing in either three-wire or four-wire systems is generally done by using an active shunt filter configuration. Neutral current compensation is carried out by inserting an active shunt filter [161]. For most of the combinations of these current-based compensations, the active shunt filter is technically the right choice

B. Voltage-Based Compensation

Voltage-based compensation is categorized as voltage harmonics compensation, improving voltage regulation, voltage balancing, voltage flicker reduction, and removing voltage sags and dips. Voltage-based compensation is carried out by using active series filters. However, the voltage flicker is compensated by using the active shunt filters. Table I shows a brief summary of active filter for compensation in order of preference. Nowadays, the active filters can also correct voltage compensation of momentary voltage dips or sags of very short duration.

Table No.1
SELECTION OF AF'S FOR SPECIFIC APPLICATION CONSIDERATIONS

Compensation for specific Application	**Active Filter**			
	Active Series Filter	**Active Shunt Filter**	**Hybrid of Active Series and Passive Shunt**	**Hybrid of Active Shunt and Active Series**
1. Current Harmonics		**	***	*
2. Reactive Power		***	**	*
3. Load Balancing		*		
4. Neutral Current		**	*	
5. Voltage Harmonics	***		**	*
6.Voltage Regulation	***	*	**	*
7. Voltage Balancing	***		**	*
8. Voltage Flicker	**	***		*
9.Voltage Sag & Dips	***	*	**	*
10. (1 + 2)		***	**	*
11. (1+2+3)		**		*
12. (1+2+3+4)		*		*
13. (5+6)	**			*
14. (5+6+7+8)	**			*
15. (1+5)			**	*
16. (1+2+5+6)			*	**
17. (6+7)	**		*	
18. (2+3)		*		
19. (2+3+4)		*		
20. (1+2+7)		**	*	
21. (1+3)		*		
22. (1+4+7)		*	**	

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AF Configuration with higher number of * is more preferred.

Here table no. 1 gives the configurations of active filters with the suitable application which is done by them. The perfect active filter for specific application can be configure out by the rating which shown in the table. The rating are with higher numbers of * showing their preference toward the active filter on the special issues which have to eliminate.

V. CONCLUSIONS

An extensive review on possible effects of grid-connected PV systems on power quality in distribution systems under varying solar irradiances has been presented to provide a clear perspective various aspects of the active power produced by PV system causes voltage rise, voltage flicker, and power factor reduction, which may create severe problems on the system components. The substantial increase in the use of power electronics devices results in harmonic pollution above the tolerable limits. Utilities are finding it difficult to maintain the power quality at the consumer end. Active filter technology is well developed and many manufacturers are manufactures active filters with large capacities. A large number of AF configurations are available to compensate harmonic current, reactive power, neutral current, unbalance current, and harmonics. Here with the issues, shunt active filter is one the best configuration which can be used to compensate these issues. So Shunt active filter can be preferred for used in grid connected PV system.

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