HARMONICS MITIGATION OF PV SYSTEM FOR NON LINEAR LOAD- AN OVERVIEW AND IMPLEMENTATION

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ABSTRACT

The harmonics distortion due to huge non linear loads is always a serious concern of any power system. The harmonics not only increases the distortion in the supply but causes the power factor to be lowered. The researchers and technocrats are working on various aspects to be improved for assured better power quality to be achieved. For the countries like India, photovoltaic will be the most contributing electricity source in coming future. This paper tries to conclude with the identification of the suitable controlling method of harmonics reduction for PV systems connected to the non linear loads through the power grid. This paper presents the operation of the mitigation technique of harmonics with active power filter (APF).

Keywords: Harmonics, mitigation methods, active and passive controllers, PV system, etc.

1.INTRODUCTION

The numerous power electronics appliances connected to electric system are nonlinear in nature. It may affect the performance of the power system such as harmonic lesser power factor and harmonic distortion. To overcome this situation, harmonic mitigation techniques are being used comprises of active filters, passive filters and hybrid filters. The filter tries to nullify the harmonics before feeding it to the grid. Paper have presented the various filters for mitigation of the harmonics to improve the performance of the PV system connected to the grid. The solar energy is being very popular in India during recent years. The government policy supports the renewable energy mainly solar. In previous days to popularize solar generation it is being subsidized by the Indian government. Being the easily available source of energy, solar systems are installed widely in India. Corporate and commercial buildings are now a day's coming up with installation of the solar roof top systems for the production of electricity with net metering facility. The clean energy is attracting the industries to earn better and to have the sustainable energy generation. The solar systems in India are now modernized as far as the performance is concerned. The cost of the setup has also been reduced in recent years and hence the system is becoming popular day by day. The flexibility and the quality power is the requirement of any electrical system. The power drawn from PV system when connected to the grid faces the issues with the harmonics distortion. Consistent performance without disturbance of the electrical supply makes any power system a reliable and trustworthy.

Renewable Energy sources are now more accepted as compare to other conventional sources due to their reliable operation, performance and their clean energy nature. Among RE sources, Photovoltaic based energy and wind energy systems are highly focused and installed in many sectors. Steady, stable and quality of power supply is of great concern in power system.Some of the issues with RE technologies are its high capital cost, transmission possibility, availability and efficiency level. While focusing a better future in power sector with PV unit, power quality measures also need to be considered. One of the main power quality issue in power system is of harmonics either it is higher order or lower order. Even current and voltage related PQ issues in power distribution system have made electrical engineers to think and design devices to mitigate these problems.

So by taking into account of PV unit and APFs, has come up with a solution PV-APF combination to supply non linear load and compensate utility current. The overall setup comprises of PV arrays, MPPT controller, a dc/dc converter (boost converter), voltage source converter (VSC), 3 phase induction motor considered as nonlinear load and utility. [14] At the end of the system, nonlinear loads are present such as computers, microwave Owens, other household appliances, and induction motors in case of industries.

1.1 Filter Technologies

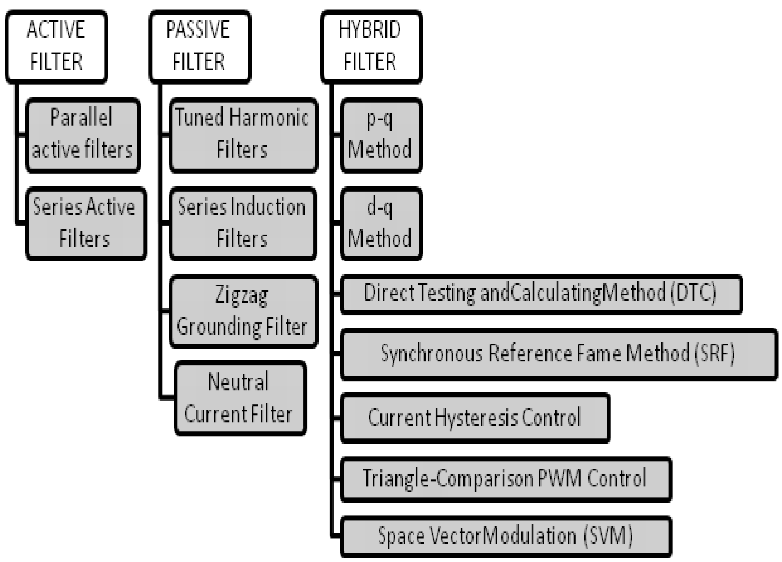


Fig.1. Classification of filter technologies

Passive Harmonic Mitigation Techniques:

Various passive filtering techniques are available for reduction in level of harmonics in electrical system which may incorporate higher pulse converter circuits e.g. 12, 18 pulse and 24 pulse. In all passive filtering technique undesirable current distortion is being blocked from flowing into grid is either by using high series inductance or diverting the flow if harmonic current by means of low impedance parallel path.

Active Harmonic Mitigation Techniques:

Basically this technique refers to the injection of the current in order to minimise the impact of harmonics. In this technique active filtration of the harmonics, the improvement in power quality is achieved by injecting equal and opposite current or voltage into electrical network thus cancelling original distortion. Active harmonics filters generally uses an insulated gate bipolar transistors (IGBT's) for production of output current of the required shape when injected into AC lines it abandons the original load generated harmonics.

Hybrid Harmonic Mitigation Techniques:

The combination of the active filter and passive filter is used for further enhancement of the results for the harmonic filter. The passive filter is used in fixed characteristics and in many of the cases it is observed that is not efficient to mitigate the current harmonics. Hence in addition to passive filter active filter is also employed to overcome the drawback of the passive harmonic filter. Active harmonic filter uses switching mode power converter for performing the harmonic current elimination. However the limitation is that, the construction cost of active harmonic filter.

2.CONTROL LOGIC FOR THE IMPLEMENTED SYSTEM:

Modified reactive power theory is the basis for the system to be controlled.The input parameters for modified IRPT control is utility voltage, non linear load currents, utility injected currents, output currents from VSC, and dc link voltage..

$$p_{load} = p_{vsc} + p_{Uti} \quad (1)$$

$$q_{load} = q_{vsc} + q_{Uti} \quad (2)$$

Using three phase to two phase transformation matrix, the instantaneous active power (p_{load}) and the instantaneous reactive power (q_{load}) of the load side can be calculated, as shown in the following equations:

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \frac{\sqrt{3}}{2} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$\begin{bmatrix} p_{load} \\ q_{load} \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix}$$

(~) sign indicates oscillating, which are realized through an low pass filter (LPF).For this a fifth order Butterworth low pass filter with cutoff frequency between 30 to 100 Hz has been used.

$$p_{load} = \bar{p}_{load} + \tilde{p}_{load} \quad (3)$$

$$q_{load} = \bar{q}_{load} + \tilde{q}_{load} \quad (4)$$

The active power is the sum of average and oscillating power fed by VSC in the addition with average utility power and extra amount of real power ($\bar{p}_{loss}$). Hence,

$$\bar{p}_{load} + \tilde{p}_{load} = \bar{p}_{vsc} + \tilde{p}_{vsc} + \bar{p}_{Uti} + \bar{p}_{loss} \quad (5)$$

$\bar{q}_{load} + \tilde{q}_{load} = \bar{q}_{vsc} + \tilde{q}_{vsc} + \bar{q}_{Uti}$(6)

$\bar{p}_{vsc} = \bar{p}_{load} - \bar{p}_{Uti} - \bar{p}_{loss}$(7)

$\bar{q}_{vsc} = \bar{q}_{load} - \bar{q}_{Uti}$(8)

$\tilde{p}_{vsc} = \tilde{p}_{load}$(9)

$\tilde{q}_{vsc} = \tilde{q}_{load}$(10)

$p^{ref}{}_{VSC} = p_{load} - \bar{p}_{Uti} - \bar{p}_{loss}$ (11)

$q^{ref}{}_{VSC} = q_{load} - \bar{q}_{Uti}$ (12)

If the extra amount of real power ($\bar{p}_{loss}$) supplied by PV unit and the PV-APF combination compensates all the imaginary power of load demand is transferred to,

$p^{ref}{}_{VSC} = p_{load} - \bar{p}_{Uti} + \bar{p}_{loss}$ (13)

$q^{ref}{}_{VSC} = q_{load}$ (14)

Using two phase to three phase transformation matrix the reference current values in the three phases are calculated using following equations:

$$\begin{bmatrix} i^{ref}\alpha_{VSC} \\ i^{ref}\beta_{VSC} \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} p^{ref}{}_{VSC} \\ q^{ref}{}_{VSC} \end{bmatrix}$$

$$\begin{bmatrix} i^{ref}a_{VSC} \\ i^{ref}b_{VSC} \\ i^{ref}c_{VSC} \end{bmatrix} = \frac{\sqrt{3}}{2} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i^{ref} \\ q^{ref} \end{bmatrix}$$

PV-APF combination is responsible for the compensation of harmonics and to aid transfer of power from PV unit to the utility. In the absence of PV unit (in case of weather disturbance or during night), the APF controller comes into action in order to operate dc link capacitor, C_{VSC} for APF function. In this case the utility must supply the constant dc link voltage regulation irrespective of the conditions.

3.SIMULATION RESULTS AND VALIDATION

The complete system shown in Fig. 2 is simulated in MATLAB/Simulink tool to analyze the PV-APF combination unit which is directly connected to the AC-utility through power converters.

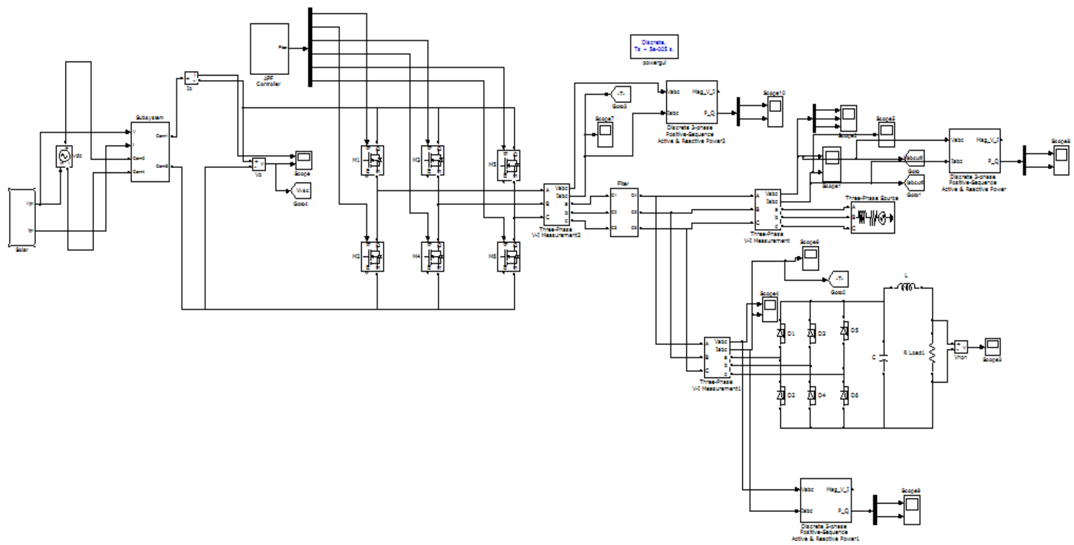


Fig. 2 Simulation diagram of proposed syste

The system is simulated to validate its ability to filter out the harmonics present in the system due to non linear loads. Fig. 3 shows the simulation diagram of the PV system. Actually the entire concept is revolving. It has around four modes of operation i.e. dq-current mode, PV-APF mode, APF mode, & utility mode.

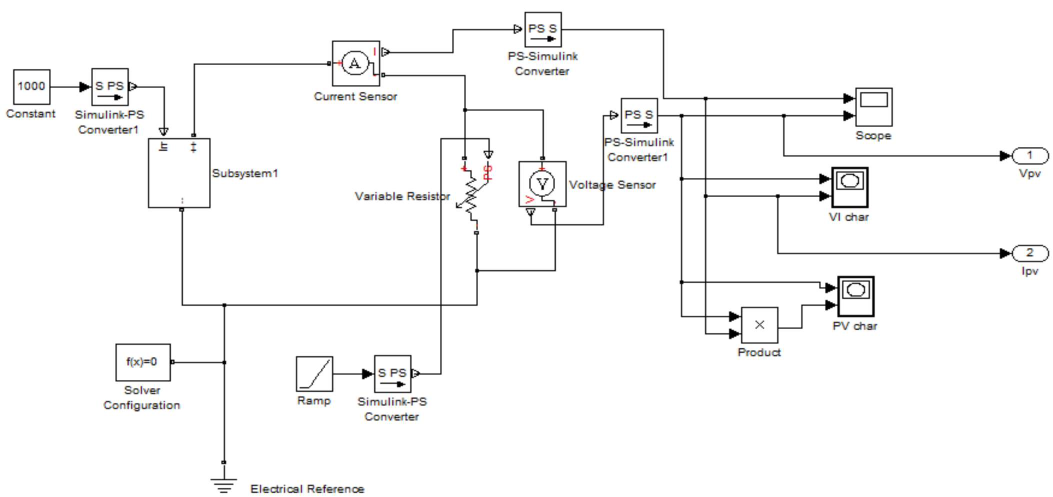
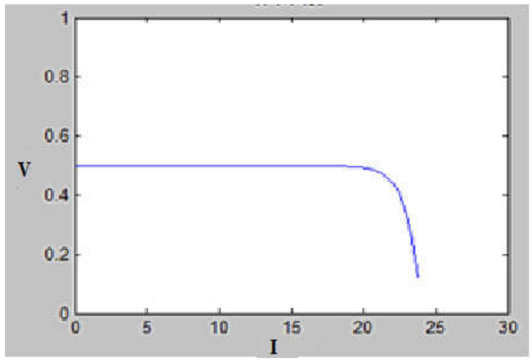


Fig.3 Simulation diagram of the PV system

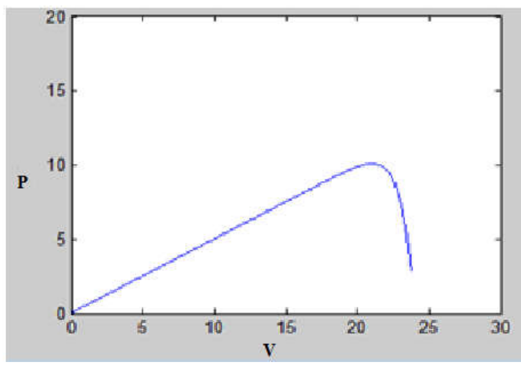
3.1 PV Unit Performance

The PV cell system is shown in Fig. 2 is simulated using MATLAB/Simpower system. The PV module is unable to deliver maximum power output when the DC/DC converter uses a fixed duty cycle i.e. in the absence of MPPT controller. As soon as the MPPT controller activates, the PV unit could generate its maximum power of 11KW.

The duty cycle is also effected and hence it changed its value from 0.5 to 0.42 whereas the voltage waveform also changed. The PV unit is isolated from the entire system during APF mode and the output active power is gradually reduced. The non linear load is also supplied by the utility in this duration. So the power flow to the non linear load is from utility rather than PV unit. The VI and PV characteristic are shown in the Fig. 4.



(a)



(b)

Fig. 4(a) VI Characteristics (b) PV Characteristics

3.2. PV-Active Power Filter Controller (p-q method)

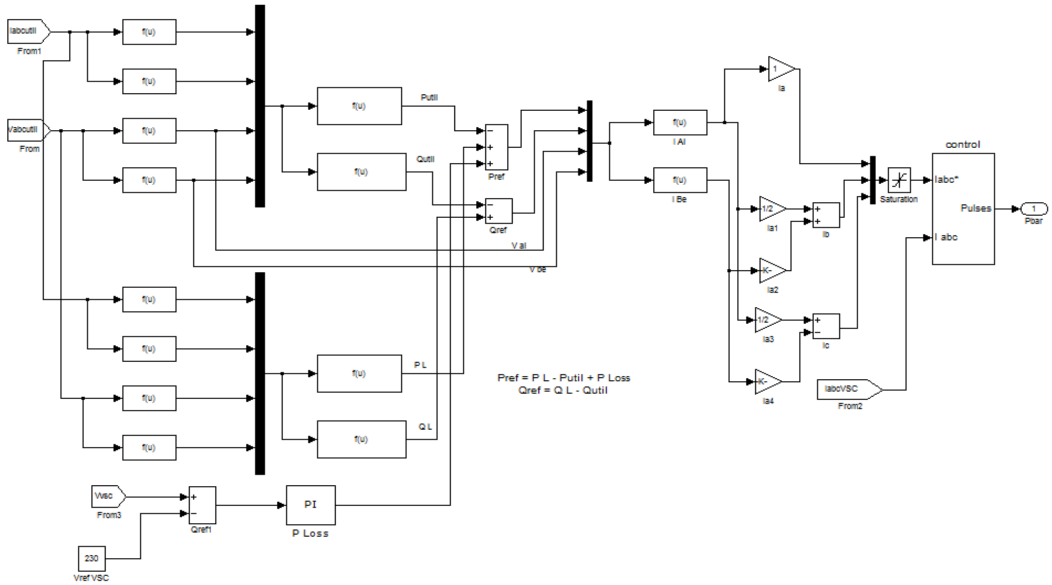


Fig. 5 PV-APF Controller

In this mode of operation, both PV unit and the utility is supplying power to the non linear load. The non linearload consumes high current for its three phases while dc current for single phase. The dc current consists of ripples is responsible for the higher order harmonics such as fifth and seventh order. The THDs will also be effected when the commutation angle of the switches been changed in the three phase controlled rectifier which in turn affects the incoming current from the utility. So the current from the utility is a major concern and most important factor in the system which is already addressed in this paper. The output utility current is shown in the Fig.4. During the APF mode, the balance currents from the utility exhibit the ability of PV-APF combination system to compensate and filter out the harmonics and unbalanced load currents.

The utility delivers average real power to the local loads even in PV-APF mode. Since in PVF mode of operation, utility alone is delivering power to the load as PV unit is isolated, hence the utility is following the load demand in this mode. In this case the output active power reduced. The utility currents are of higher level in APF mode as compare to the PV-APF mode.

The instantaneous real and reactive powers at three portions including PV unit, the utility and at load is addressed with respect to different modes:

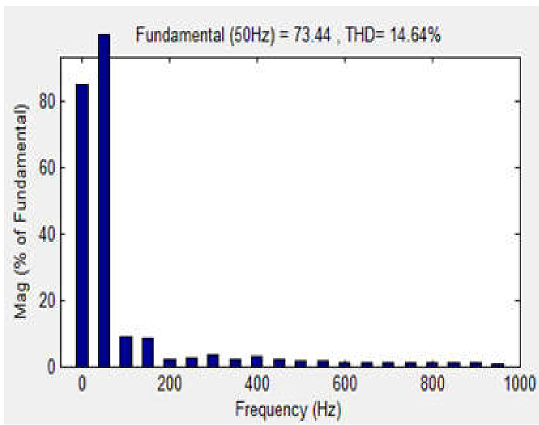
1. dq current mode: The real power from utility and PV unit consists of average and oscillating components as the dq controller is affected by the non linear load as discussed in this paper already. Similarly reactive power of utility and PV unit has both components in it.

2. PV-APF mode: During this mode utility real power contains only average component whereas PV real power holds both the components. PV reactive power consists of both components; hence the PV real power reduces when PV reactive power increases gradually.

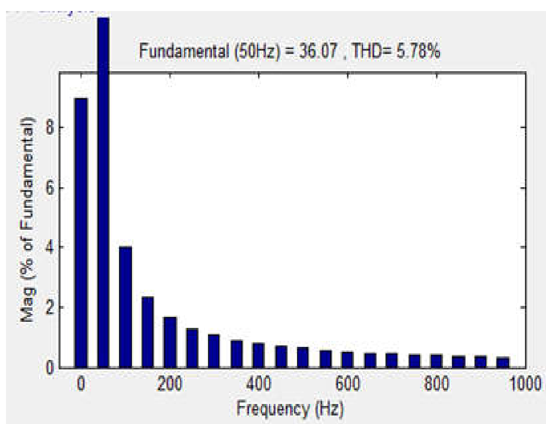
3. APF mode: Real and reactive power of utility supplies only average components in this mode of operation. The oscillating part of the load is fed by the dc link of the VSC.

5. Utility mode: Only utility supplies power to the load. Real and reactive power of the utility will be exactly equal to the load powers.

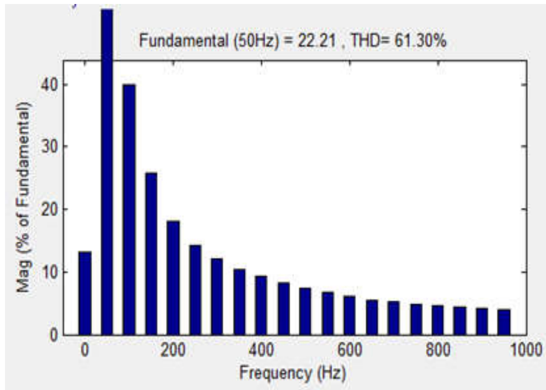
The filtering effect of the PV-APF controller is also feasible to design when the utility receives power from the PV system. The design of PV-APF controller is based on instantaneous power balance. When the load consumes dc current in case of three phase rectifier or single phase rectifier, the utility is supplied from the PV system instead of supplying currents to the load. Hence, the utility currents are made sinusoidal in PV-APF and APF alone mode using the controller. The THDs at three portions as mentioned above are depicted in Fig 9.



(a)



(b)



(c)

Fig 9. THDs at (a) APF mode (b) PV-APF mode (c) utility mode

4.CONCLUSION

The non-linear loads are always connected to every electrical system. The problems with such load are the harmonic distortion and hence to improve the harmonics performance of the system various controllers are to be used. Authors have presented the brief information about the various controllers available to address this problem and concluded that the P-Q method is found suitable for the PV system. The P-Q method is implemented in this paper and the MATLAB results are presented.

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