

INTEGRATION OF SOLAR PV INTO GRID USING A NEW UPQC WITH DIFFERENTIAL INVERTER CONTROL

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Abstract— In this work, a novel technique based on second order sequence filter and proportional resonant controller is proposed for control of universal active power filter integrated with PV array (UAPF-PV). Using a second order sequence filter and sampling it at zero crossing instant of the load voltage, the active component of distorted load current is estimated, which is used to generate reference signal for shunt active filter. The proposed method has good accuracy in extracting fundamental active component of distorted and unbalanced load currents with reduced mathematical computations. Along with power quality improvement, the system also generates clean energy through the PV array system integrated to its DC-link. The UAPF-PV integrates benefits of power quality improvement and distributed generation. The system performance is experimentally evaluated on a prototype in the laboratory under a variety of disturbance conditions such as PCC voltage fall/rise, load unbalancing and variation in solar irradiation.

Index Terms—power quality, universal active power filter, adaptive filtering, photovoltaic array, maximum power point tracking, sequence filter..

Keywords— solar PV, grid , UPQC

I. INTRODUCTION

There has been an ever increasing focus on installation of renewable energy sources such as solar photovoltaic (PV) and wind energy systems with the grid . This has been facilitated due to development of reliable and efficient power converters, improved efficiency of PV panels and decreasing costs of manufacturing. However, with the increasing penetration of renewable energy sources, which are intermittent sources of energy, fluctuations in voltage at the point of common coupling (PCC), have also increased. These loads also cause losses in feeders and distribution transformers. Moreover, these loads themselves are sensitive to PCC voltage dip/rise, which causes frequent tripping and increased maintenance costs. Hence, the major requirement of modern distribution system is the integration of renewable energy systems along with power quality improvement. In order to improve power quality, various improved quality devices based on power factor correction (PFC), have been researched upon and developed. However, these are mainly suitable

at low and medium power levels and is only cost effective when developing a completely new system . Custom power devices such as distribution static compensator (DSTATCOM), dynamic voltage restorer (DVR) and unified power quality conditioner (UPQC) which is also known as unified active power filter (UAPF), are used as retrofit solution for power quality improvement in large scale industrial systems. An integration of solar PV array along with custom power devices, provides dual solution of power quality improvement along with solar energy. A solar PV integrated distribution static compensator (PV-DSTATCOM) has been proposed . This system has dual role of generation of power from renewable sources along with compensation of load current harmonics generated due to nonlinear loads. These are then used to generate reference signals for the operation of the shunt active filter. This technique has improved precision in extracting active component of distorted load current with good dynamic performance. • A multifunctional topology which integrates clean energy generation along with power quality improvement. • It protects sensitive loads from PCC voltage dip/rise along with compensating nonlinear current drawn by the load. • Use of second order sequence filter, which is inherently a three phase filter along with zero cross detection technique gives improved accuracy in extraction of load current active component of all three phases with a single sample and hold operation. This prototype is then subjected to various dynamic conditions such as voltage sags/swells, solar irradiation and load unbalance to evaluate its performance under dynamic conditions..

II. POWER QUALITY

2.1 CLASSIFICATION OF POWER QUALITY PROBLEMS

This IEEE defined power quality disturbances shown in this paper have been organized into seven categories based on wave shape:

1. Transients.

2. Interruptions.
3. Sag / under voltage.
4. Swell / Overvoltage.
5. Waveform distortion.
6. Voltage fluctuations.
7. Frequency variations.

2.1.1 Transients:

Potentially the most damaging type of power disturbance, transients fall into two subcategories:

1. Impulsive
2. Oscillatory

Impulsive:

Impulsive transients are sudden high peak events that raise the voltage and/or current levels in either a positive or a negative direction. These types of events can be categorized further by the speed at which they occur (fast, medium and slow). Impulsive transients can be very fast events (5 nanoseconds [ns] rise time from steady state to the peak of the impulse) of short-term duration (less than 50 ns).

Note: [1000 ns = 1 μ s] [1000 μ s = 1 ms] [1000 ms = 1 second]

One example of a positive impulsive transient caused by electrostatic discharge (ESD) event is illustrated

Oscillatory:

An oscillatory transient is a sudden change in the steady-state condition of a signal's voltage, current or both at the positive and negative signal limits oscillating at the natural system frequency. In simple terms the transient causes the power signal to alternately swell and then shrink very rapidly. Oscillatory transients usually decay to zero within a cycle (a decaying oscillation).

These transients occur when you turn off an inductive or capacitive load such as a motor or capacitor bank. An oscillatory transient results because the load resists the change. This is similar to what happens when you suddenly turn off a rapidly flowing faucet and hear a hammering noise in the pipes. The flowing water resists the change and the fluid equivalent of an oscillatory transient occurs.

For example upon turning off a spinning motor it acts briefly as a generator as it powers down, thereby producing electricity and sending it through the electrical distribution. A long electrical distribution system can act like an oscillator when power is switched on or off, because all circuits have some inherent inductance and distributed capacitance that briefly energizes in a decaying form.

When oscillatory transients appear on an energized circuit, usually because of utility switching operations (especially when capacitor banks are automatically switched into the system), they can be quite disruptive to electronic equipment. a typical low frequency Oscillatory Transient attributable to capacitor banks being energized.

2.1.2. Interruptions:

An interruption is defined as the complete loss of supply voltage or load current. Depending on its duration, an interruption is categorized as instantaneous, momentary, temporary, or sustained.

Types

- a) Instantaneous 0.5 to 30 cycles.
- b) Momentary 30 cycles to 2 seconds.

Solutions to help against interruptions vary, both in effectiveness and cost. The first effort should go into eliminating or reducing the likelihood of potential problems. Good design and maintenance of utility systems are, of course, essential. This also applies to the industrial customer's system design, which is often as extensive and vulnerable as the utility system.

2.1.3. Sag / under voltage:

Sag is a reduction of AC voltage at a given frequency for the duration of 0.5 cycles to 1 minute's time. Sags are usually caused by system faults, and are also often the result of switching on loads with heavy start-up currents. Some of the same techniques that were used to address interruptions can be utilized to address voltage sags: UPS equipment, motor generators, and system design techniques. However, sometimes the damage being caused by sags is not apparent until the results are seen over time. Under voltages are the results of long-term problems that create sags. The term "brownout" has been commonly used to describe this problem, and has been super ceded by the term under voltage. Under-voltages can create overheating in motors, and can lead to the failure of nonlinear loads such as computer power supplies. The solution for sags also applies to under-voltages. More importantly, if an under voltage remains constant, it may be a sign of a serious equipment fault, configuration problem, or that the utility supply needs to be addressed.

PHOTOVOLTAIC TECHNOLOGY

3.1 SOLAR CELLS:

The solar cell is the elementary building block of the photovoltaic technology. Solar cells are made of semiconductor materials, such as silicon. One of the properties of semiconductors that makes them most useful is that their conductivity may easily be modified by introducing impurities into their crystal lattice. For instance, in the fabrication of a photovoltaic solar cell, silicon, which has four valence electrons, is treated to increase its conductivity. On one side of the cell, the impurities, which are phosphorus atoms with five

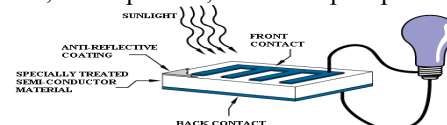


Fig: 3.1 solar cell

The photovoltaic effect was first reported by Edmund Becquerel in 1839 when he observed that the action of light on a silver coated platinum electrode immersed in electrolyte produced an electric current. Forty years later the first solid state photovoltaic devices were constructed by workers investigating the recently discovered photoconductivity of selenium. In 1876 William Adams and Richard Day found that a photocurrent could be produced in a sample of selenium when contacted by two heated platinum contacts. The photovoltaic action of the selenium differed from its photoconductive action in that a current was produced spontaneously by the action of light.

3.2 ELECTRICAL CONNECTION OF THE CELLS

The electrical output of a single cell is dependent on the design of the device and the

Semi-conductor material(s) chosen, but is usually insufficient for most applications. In order to provide the appropriate quantity of electrical power, a number of cells must be electrically connected. There are two basic connection methods: series connection, in which the top contact of each cell is connected to the back contact of the next cell in the sequence, and parallel connection, in which all the top contacts are connected together, as are all the bottom contacts. In both cases, this results in just two electrical connection points for the group of cells.

Series connection:

Figure shows the series connection of three individual cells as an example and the resultant group of connected cells is commonly referred to as a series string. The current output of the string is equivalent to the current of a single cell, but the voltage output is increased, being an addition of the voltages from all the cells in the string (i.e. in this case, the voltage output is equal to $3V_{cell}$).

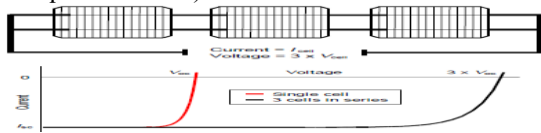


Fig 3.2. Series connection of cells, with resulting current-voltage characteristic.

It is important to have well matched cells in the series string, particularly with respect to current. If one cell produces a significantly lower current than the other cells (under the same illumination conditions), then the string will operate at that lower current level and the remaining cells will not be operating at their maximum power points.

Parallel connection

Figure shows the parallel connection of three individual cells as an example. In this case, the current from the cell group is equivalent to the addition of the current from each cell (in this case, $3 I_{cell}$), but the voltage remains equivalent to that of a single cell.

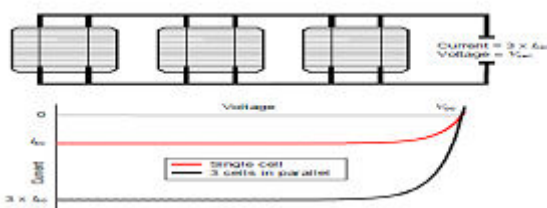


Fig 3.3 Parallel connection of cells, with resulting current-voltage characteristic.

3.2.1 THE PHOTOVOLTAIC ARRAY

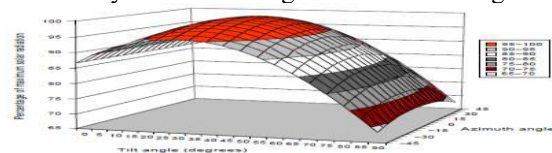
A PV array consists of a number of PV modules, mounted in the same plane and electrically connected to give the required electrical output for the application. The PV array can be of any size from a few hundred watts to hundreds of kilowatts, although the larger systems are often divided into several electrically independent sub arrays each feeding into their own power conditioning system.

3.2.2 MOUNTING STRUCTURE

The main purpose of the mounting structure is to hold the modules in the required position without undue stress. The structure may also provide a route for the electrical wiring and may be free standing or part of another structure (e.g. a building). At its simplest, the mounting structure is a metal framework, securely fixed into the ground. It must be capable of withstanding appropriate environmental stresses, such as wind loading, for the location. As well as the mechanical issues, the mounting has an influence on the operating temperature of the system, depending on how easily heat can be dissipated by the module.

3.2.3 TILT ANGLE AND ORIENTATION:

The orientation of the module with respect to the direction of the Sun determines the intensity of the sunlight falling on the module surface. Two main parameters are defined to describe this. The first is the tilt angle, which is the angle between the plane of the module and the horizontal. The second parameter is the azimuth angle, which is the angle between the plane of the module and due south (or sometimes due north depending on the definition used). Correction of the direct normal irradiance to that on any surface can be determined using the cosine of the angle between the normal to the Sun and the module plane. The optimum array orientation will depend on the latitude of the site, prevailing weather conditions and the loads to be met. It is generally accepted that, for low latitudes, the maximum annual output is obtained when the array tilt angle is roughly equal to the latitude angle and the array faces due south (in the northern hemisphere) or due north (for the southern hemisphere). For higher latitudes, such as those in northern Europe, the maximum output is usually obtained optimum for tilt angles of approximately the latitude angle minus 10–15 degrees.



Percentage variation of annual sunlight levels as a function of tilt angle and azimuth angle.

3.3 SUN-TRACKING/CONCENTRATOR SYSTEMS

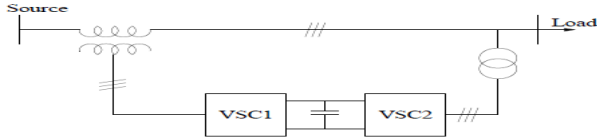
The previous section has assumed a fixed array with no change of orientation during operation. This is the usual configuration for a flat-plate array. However, some arrays are designed to track the path of the Sun. This can account fully for the sun's movements by tracking in two axes or can account partially by tracking only in one axis, from east to west.

UNIFIED POWER QUALITY CONDITIONER

4.1 UPQC:

The provision of both DSTATCOM and DVR can control the power quality of the source current and the load bus voltage. In addition, if the DVR and STATCOM are

connected on the DC side, the DC bus voltage can be regulated by the shunt connected DSTATCOM while the DVR supplies the required energy to the load in case of the transient disturbances in source voltage. The configuration of such a device (termed as Unified Power Quality Conditioner (UPQC)) is shown in Fig. 14.15. This is a versatile device similar to a UPFC. However, the control objectives of a UPQC are quite different from that of a UPFC.



5.1.1 CONTROL OBJECTIVES OF UPQC

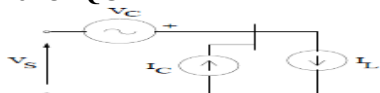
The shunt connected converter has the following control objectives

1. To balance the source currents by injecting negative and zero sequence components required by the load
2. To compensate for the harmonics in the load current by injecting the required harmonic currents
3. To control the power factor by injecting the required reactive current (at fundamental frequency)
4. To regulate the DC bus voltage.

The series connected converter has the following control objectives

1. To balance the voltages at the load bus by injecting negative and zero sequence voltages to compensate for those present in the source.
2. To isolate the load bus from harmonics present in the source voltages, by injecting the harmonic voltages
3. To regulate the magnitude of the load bus voltage by injecting the required active and reactive components (at fundamental frequency) depending on the power factor on the source side
4. To control the power factor at the input port of the UPQC (where the source is connected. Note that the power factor at the output port of the UPQC (connected to the load) is controlled by the shunt converter.

Operation of UPQC



The operation of a UPQC can be explained from the analysis of the idealized equivalent circuit shown in Fig. 14.16. Here, the series converter is represented by a voltage source V_C and the shunt converter is represented by a current source I_C . Note that all the currents and voltages are 3 dimensional vectors with phase coordinates. Unlike in the case of a UPFC (discussed in chapter 8), the voltages and currents may contain negative and zero sequence components in addition to harmonics. Neglecting losses in the converters, we get the relation

$$\langle V_L, I_C \rangle + \langle V_C, I_S \rangle = 0$$

where X, Y denote the inner product of two vectors, defined by

$$\langle X, Y \rangle = \frac{1}{T} \int_0^T X^t(\tau) Y(\tau) d\tau.$$

Let the load current I_L and the source voltage V_S be decomposed into two Components given by

$$I_L = I_L^{1p} + I_L^x$$

$$V_S = V_S^{1p} + V_S^x$$

Where I_L^{1p} contains only positive sequence, fundamental frequency components. Similar comments apply to V_S^{1p} . I_L^x and V_S^x contain rest of the load current and the source voltage including harmonics. I_L^{1p} is not unique and depends on the power factor at the load bus. However, the following relation applies for I_L^{1p} .

$$P_L = \langle V_L, I_L \rangle = \langle V_L, I_L^{1p} \rangle$$

This implies that $\langle I_L^x, V_L \rangle = 0$. Thus, the fundamental frequency, positive sequence component in I_L^x does not contribute to the active power in the load. To meet the control objectives, the desired load voltages and source currents must contain only positive sequence, fundamental frequency components and

$$P_L = |V_L^* I_S^*| \cos \phi_L = |V_S^{1p} I_S^*| \cos \phi_s$$

where $V \square L$ and $I \square S$ are the reference quantities for the load bus voltage and the source current respectively. ϕ_L is the power factor angle at the load bus while ϕ_s is the power factor angle at the source bus (input port of UPQC). Note that $V \square L(t)$ and $I \square S(t)$ are sinusoidal and balanced. If the reference current ($I \square C$) of the shunt converter and the reference voltage ($V \square C$) of the series converter are chosen as

$$I_C^* = I_L^*, \quad V_C^* = -V_S^* + V_C^{1p}$$

with the constraint

$$\langle V_C^{1p}, I_S^* \rangle = 0$$

we have,

$$I_S^* = I_L^{1p}, \quad V_L^* = V_S^{1p} + V_C^{1p}$$

Note that the constraint (14.30) implies that V_C^{1p} is the reactive voltage in quadrature with the desired source current, $I \square S$. It is easy to derive that $\langle V_C^*, I_S^* \rangle = 0 = \langle I_C^*, V_L^* \rangle$. The above equation shows that for the operating conditions assumed, a UPQC can be viewed as a inaction of a DVR and a STATCOM with no active power flow through the DC link. However, if the magnitude of $V \square L$ is to be controlled, it may not be feasible to achieve this by injecting only reactive voltage. The situation gets complicated if V_L^{1p} is not constant, but changes due to system disturbances or fault. To ensure the regulation of the load bus voltage it may be necessary to inject variable active voltage (in phase with the source current). If we express

$$V_C = V_C^* + \Delta V_C, I_C = I_C^* + \Delta I_C$$

$$I_S = I_S^* - \Delta I_C, V_L = V_S^{1p} + V_C^{1p} + \Delta V_C$$

$$\langle I_S, \Delta V_C \rangle + \langle V_L, \Delta I_C \rangle = 0$$

In deriving the above, we assume that

$$\langle I_S, V_C^* \rangle = 0 = \langle V_L, I_C^* \rangle$$

This implies that both ϕV_C and ϕI_C are perturbations involving positive sequence, fundamental frequency quantities (say, resulting from symmetric voltage sags). the power

balance on the DC side of the shunt and series converter. The perturbation in VC is initiated to ensure that

$$|V_C + \Delta V_C + V_S| = |V_L| = \text{constant.}$$

Thus, the objective of the voltage regulation at the load bus may require exchange of power between the shunt and series converters.

Remarks

1. The unbalance and harmonics in the source voltage can arise due to uncompensated nonlinear and unbalanced loads in the upstream of the UPQC.
2. The injection of capacitive reactive voltage by the series converter has the advantage of raising the source voltage magnitude

CONFIGURATION OF PV-UAPF SYSTEM

5.1 GURATIONCONFI OF PV-UAPF SYSTEM

presents the structure of UAPF-PV systems. The topology is a three phase double stage configuration in which a boost DC-DC converter interfaces the PV array to the DC-link of UAPF. The compensators are connected to the distribution system through filter inductors. The series active filter applies voltage in series with the PCC through series transformers. Ripple filters consisting of series connection of resistors and capacitors, are used in both series and shunt voltage source converters (VSCs) to filter out higher order harmonics generated due to switching action of series and shunt active filters.

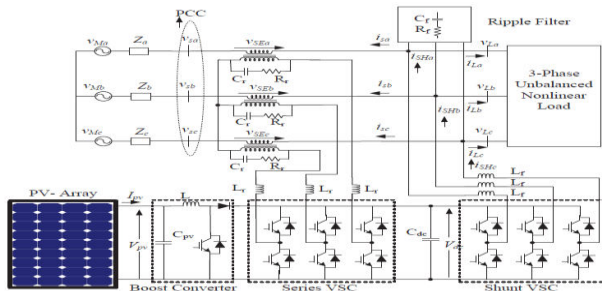


Fig. 6.1 System configuration of UAPF-PV System

6.1.1 SYSTEM CONTROL

The primary objective of UAPF-PV system is to compensate for harmonics due to nonlinear load and protect sensitive loads from PCC voltage dip/rise. Along with power quality improvement, UAPF-PV system also performs the function of clean energy generation by supplying PV power into distribution system. The control aspects of shunt active filter and series active filter, are explained as follows. A. Control of Shunt Active Filter The block diagram for the control of shunt active filter is presented in Fig. 2(b). In this control structure, a second order sequence filter is used to extract the fundamental positive sequence component of distorted load current. The structure of second order sequence filter, is shown in Fig.2(a). Sequence filters are inherently suitable in three phase systems as they extract the fundamental positive sequence components. The open-loop transfer function of the second order sequence filter, is given as follows,

$$G_{sosl}(s) = \frac{K_1 K_2}{(s - j\omega' + K_2)(s - j\omega')} \quad (1)$$

The closed loop transfer function of (1) is given as,

$$G_{clsl}(s) = \frac{K_1 K_2}{(s - j\omega' + K_2)(s - j\omega') + K_1 K_2} \quad (2)$$

There are two controlling gains in this structure namely K1, K2. The values of K1 and K2 are a compromise between accuracy in extraction of fundamental positive sequence component and the dynamic response. Detailed analysis regarding the filter gain selection is given in [14]. The fundamental frequency positive sequence component (FPSC) of load current, is estimated, using second order sequence filter. Once the FPSC of load current is estimated, then magnitude corresponding to load current active component is extracted by sampling the current at the zero crossing of β component of load voltage. The grid current magnitude is composed of three fundamental active components i.e. a) Grid currents due to equivalent fundamental active load power at nominal PCC voltage (I_{Lp}), grid current corresponding to PV power (I_{pvg}), and loss component corresponding to losses occurring due to switching action of semiconductor switches, losses in filters etc. This is given by the following equation as,

$$I_s^* = I_{Lp} - I_{pvg} + I_{loss} \quad (3)$$

The equivalent grid current corresponding to load active power is given as,

$$I_{Lp} = K \times I_{Lap} \quad (4)$$

where

$$K = \frac{V_{Lp}}{V_s} \quad (5)$$

V * L is magnitude of reference load voltage and Vs is the magnitude of PCC voltage. The grid current corresponding to PV power, is obtained as,

$$I_{pvg} = \frac{2 P_{pv}}{3 V_s} \quad (6)$$

where Ppv is PV array power, Vs is magnitude of PCC voltage. A proportional integral (PI) controller regulates the DC-link voltage of the UAPF-PV system at desired value. The PI controller gives the component corresponding to losses in the converter and filter circuits. The control equation for the DClink PI controller, is given as,

$$I_{loss}(n) = I_{loss}(n-1) + K_p \Delta e_{vdc}(n) + K_i e_{vdc}(n) \quad (7)$$

where Iloss is the output of PI controller, which is also the loss component of UAPF-PV system, Kp and Ki are the gains of PI controller and Δe_{vdc} is the difference in DC-link voltage error between the present and past sampling time. e_{vdc} is the DC-link voltage error. The magnitude of PCC voltage (V_s), and the PCC voltage in-phase templates are evaluated

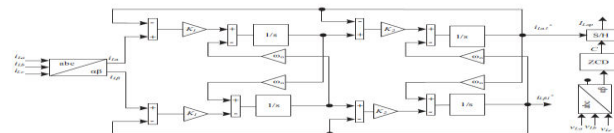


Fig. 6.2 Load Active Component Extraction Using Second Order Sequence Filter

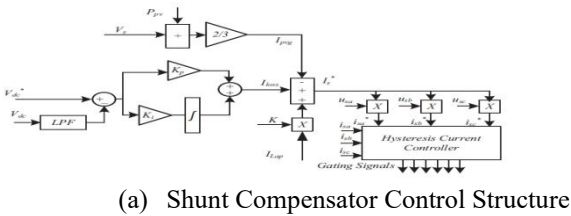
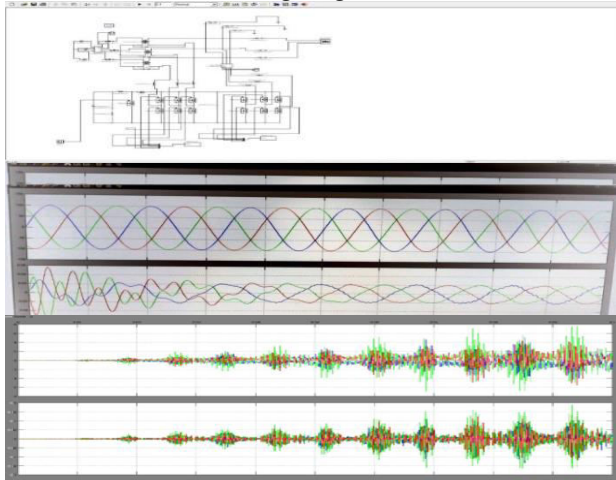


Fig. 6.3 Shunt Compensator Control Based on second order sequence filter Filter

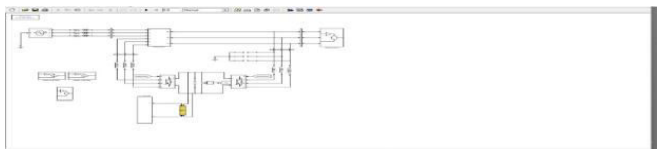
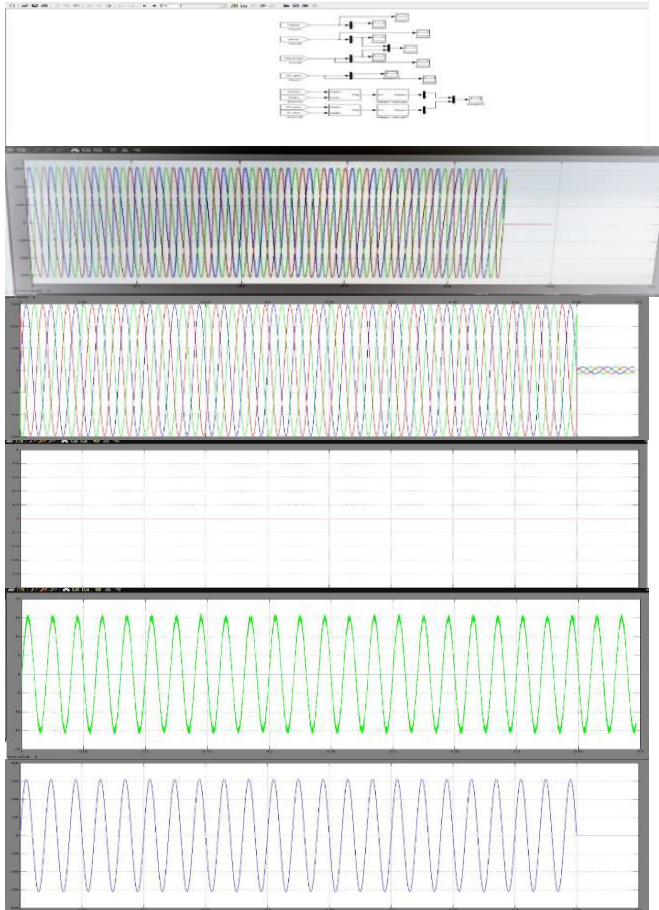
which then is multiplied with reference magnitude to generate instantaneous shunt active filter reference currents (i^*_{sa} , i^*_{sb} , i^*_{sc}) [8]. The error between (i^*_{sa} , i^*_{sb} , i^*_{sc}) and (i_{sa} , i_{sb} , i_{sc}) is passed through the hysteresis controller, which generates gating pulses for controlling the shunt compensator.

MATLAB AND SIMULATION RESULT: The system is tested under various dynamic conditions such as load balance, irradiation variation, voltage sag/swell etc.



A.Simulated performance of UAPF-PV System under PCC Voltage Sag/Swell

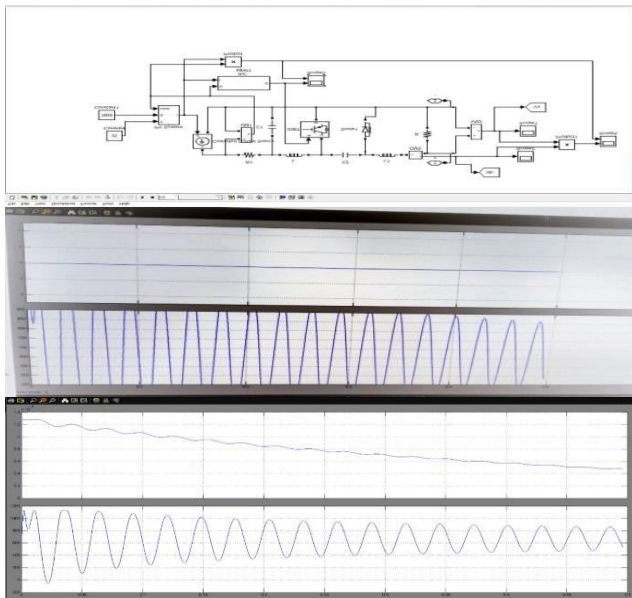
shows the performance of UAPF-PV under sags/swells in PCC voltages. The signals captured, are three phase PCC voltages v_{sabc} , load voltages (v_{labc}), series compensator voltages (v_{seabc}), DC-link voltage (V_{dc}), grid currents (i_{sabc}), load currents (i_{labc}), shunt compensator currents (i_{shabc}), PV array power (P_{pv}) and PV array voltage (V_{pv}). The PV array irradiation is maintained constant at $G = 1000\text{W/m}^2$. From $t=0.65\text{s}$ to 0.7s , the PCC voltages dips to 0.7pu and between 0.75s to 0.8s the PCC voltages rise to 1.3pu . It can be observed that under both these conditions the load voltages are regulated at its desired value. The grid currents are sinusoidal and the DC link voltage is also regulated at its preset value. There is rise in the grid current in voltage sag condition and a decrease in current during voltage swell condition in order to maintain power balance



B. Simulated performance of UAPF-PV System under Load Unbalance Condition The performance of UAPF-PV system under load unbalanced condition is given. The signals shown, are three phase PCC voltages v_{sabc} , load voltages v_{labc} , DC-link voltage V_{dc} , grid currents i_{sabc} , load currents i_{labc} , shunt compensator currents i_{shabc} , PV array power P_{pv} and PV array voltage V_{pv} . The PV array irradiation is maintained constant at $G = 1000\text{W/m}^2$. At $t=0.6\text{s}$, the phase 'A' load is removed. It can be observed that the DC-link voltage is regulated at its desired voltage of 700 V . There is ripple present in DC-link voltage, which is due to double harmonic component present during unbalanced loading condition. The shunt compensator of UAPF-PV system compensates for the unbalanced loading and it maintains the PCC currents balanced and sinusoidal within couple of cycles.

Simulated Performance of UAPF-PV Sytem at Irradiation Variation Condition

The performance of UAPF-PV system under irradiation variation condition is presented. The signals shown, are three phase PCC voltages v_{sabc} , load voltages v_{labc} , DC-link voltage V_{dc} , grid currents i_{sabc} , load currents i_{labc} , shunt compensator currents i_{shabc} , PV array power P_{pv} and PV array voltage V_{pv} and irradiation intensity $G(\text{W/m}^2)$. From $t=0.6\text{s}$ to $t=0.65\text{s}$, the solar irradiation is varied from 1000W/m^2 to 500W/m^2 . Due to reduction in the PV power generated, there is reduction in the current injected into the grid. The system DC-link voltage is regulated at its desired value of 700 V .



Simulated Performance of the System under Steady State Conditions

The steady state performance of the system is presented in . The harmonic spectra and total harmonic distortion of the grid current and load current is presented respectively. It can be observed that while the load current total harmonic distortion (THD) is 28.61%, the grid current THD is 1.69% which is within the limits prescribed in the IEEE-519 standard.

CONCLUSION & REFERENCES

CONCLUSION:

The performance of a novel control technique for solar PV system with universal active filtering, has been evaluated. The fundamental positive sequence components of nonlinear load currents are extracted using a second order sequence filter along with a zero cross detection technique. The series active filter is controlled using a proportional resonant controller implemented in $\alpha - \beta$ domain along with feedforward component. The system performs satisfactorily under disturbances such as PCC voltage dip/rise, changes in solar radiation and load disturbances. Apart from improving power quality, the system also supplies power from a PV array into the grid. A comparison of the proposed control shows that the system has improved performance as compared to conventional control techniques with low computational burden. The system integrates distributed generation along with enhancing power quality of distribution system.

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