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Maximum Power Point Tracking (MPPT) Techniques: More Proficient Use of Solar Photovoltaic Systems

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***Abstract*: In an attempt to fulfill the ever-increasing demand for electricity with the limited sources of fossil fuel and growing concern over increasing pollution have pushed mankind to explore new non-conventional, renewable energy resources such as solar energy, wind energy, biomass, tidal, geothermal, etc. Solar power proved to be one of the best alternative renewable energy sources; since it is free, clean, abundant in nature, and environment friendly. A photovoltaic cell is used to capture the sun's radiation. When sun rays are incident on the solar cell, due to photovoltaic effect light energy is directly converted to electrical energy; maximum power point tracking algorithms help to improve the output power of the PV cell. These panels can be fixed on a ground at a particular angle or can be used in a solar tracking system. In solar tracking system solar panel is made to rotate either in a single-axis or in dual axis. This paper consists of different types of MPPT techniques, cell types, and their relative comparison. It also consists of modeling of grid-connected PV array. Power electronic converters play a major role in utilizing these renewable energy sources. A proper control scheme is required to operate power converter, battery, circuit breaker and inverter to match the grid requirements also focuses on power quality improvement, harmonic distortion, and their elimination methods in the system.**

Keywords— Renewable energy system (RES), Solar energy, Photovoltaic (PV), Modeling, Maximum power point tracking (MPPT), Power quality and Harmonics.

I. INTRODUCTION

Energy policies have pushed for various technologies to decrease pollutant emissions and reduce global climate change. There are isolated areas where access to an electricity grid is just too expensive. Diesel generators were wont to provide electricity to those isolated areas. They need low initial costs but have high running and maintenance costs. They pollute the environment by producing 3kg of C02 gas for every litter of diesel fuel. To avoid environmental pollution, global warming and the ozone layer damage renewable energy sources are suitable alternatives. Among all renewable energy sources (such as wind, solar, geothermal, etc) solar photovoltaic energy is mostly used because of its clean, pollution-free, and inexhaustible nature.

Photovoltaic technology is an attractive alternative energy source because it is renewable, safe, and domestically secure. PV cells by directly converting solar energy to electrical energy generate electric power due to the reason that the voltage and current output of a single PV cell is very less for practical usage. Therefore, in order to obtain the required voltage and current output, PV generation systems generally consist of series-parallel combinations of PV cells which are known as PV panels and arrays which generate DC power which further has to be converted to AC at standard power frequency in order to feed the loads.

PV systems are provided with fine converter systems for the DC-AC conversions.. The function of the converter system is to keep the AC output voltage at the specified level despite the variation of the DC voltage and the variation of solar irradiance E (W/m2). The Inverter helps in the conversion of low voltage DC into higher voltage AC. Electricity is transferred more efficiently at higher voltages and it is the standard that is used worldwide. Inverters are available in a wide range of wattage capabilities. Altered sine wave inverters are a great option for smaller sized PV systems. When there is an excess of energy coming in, then the battery stores it and distributes it back out when there is a rise in demand. Solar PV panels continue to re-charge batteries each day to maintain battery charge [2-9, 11and 26].The maximum power point tracking (MPPT) is a technique used commonly with photovoltaic solar systems to maximize power extraction under all conditions. PV solar systems come in many different setups according to their relationships to different systems like inverter systems, external grids, battery banks, or other electrical loads. Under normal operating conditions, when grid power is available, the PV system is disconnected from supplying the local and critical loads, but whenever grid power is lost, the PV system is automatically connected to the utility grid. The PV system is designed to work as a backup power supply to provide power to the critical loads during the unavailability of grid power supply because of any fault or routine shutdown.

In electrical grids, the cluster of transmission grids, distribution grids, distributed generation, and loads that have connection points called buses, together form the power system network. Solar energy gathered by PV solar panels, intended for delivery to a power grid must be conditioned or processed for use by a grid-connected inverter. The grid-connected PV system supplied the excess power, beyond consumption by the connected load to the utility grid. Climatic change and the need to manage diminishing fossil fuel reserves are today two of the biggest challenges faced by the planet. In order to secure the future for ourselves and generation to follow, it is widely accepted that we must act now to reduce energy consumption and substantially cut greenhouse gases, such as carbon dioxide. Since PV generates electricity from photons, PV does not produce any air pollution or hazardous waste. It doesn't require liquid or gaseous fuel to be transported or combusted [2-11].

II. SYSTEM DESCRIPTION

A. Block Diagram

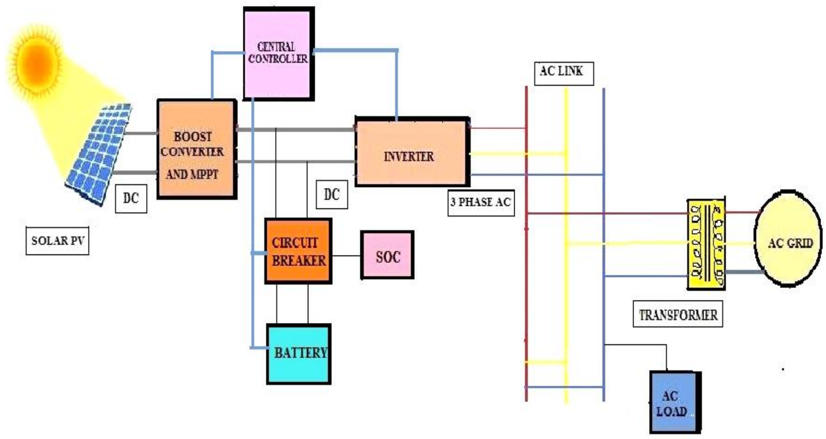

Fig. 1 Diagram of AC link.

B. Explanation

i. The system consists of solar PV which absorbs the radiations coming from the sun towards the solar panel and generates the dc power. This dc power further provided to the boost converter. The boost converter also contains the MPPT technique. In this way the boost converter is able to enhance the dc power level and the maximum power from the panel is achieved through the MPPT technique.

ii. A battery is provided to store the DC power. The ‘State Of Charge’ of a battery is the available capacity expressed as a percentage, sometimes its rated capacity but more likely its current capacity. Measuring and knowing the SOC of a battery or battery bank is useful when it is applying towards alternative energy or any other situation.

iii. A circuit breaker is also connected between transmission lines and the battery.

iv. Now the power from the boost converter is transmitted to the inverter. This inverter converts the DC power to AC, and an AC link is followed the inverter.

v. A step-up transformer is connected between the AC grid and the AC link [2].

C. Modeling of Solar PV System

The basic equation from the theory of semiconductors that mathematically describes I-V characteristics of the PV cell is given by,

$$I = I_{pv.cell} - I_D$$

Where IPVcell is the current generated by incident light and ID is the diode current. The equation for saturation current I0 given below,

$$I_0 = \frac{I_{scn} + KI\Delta T}{\frac{\exp\left((V_{OC} + Kv\Delta t\right)}{aVt} - 1}$$

Equation of photovoltaic panel Ipv is given below;

$$I_{PV} = (I_{pvn} + K_1\Delta T)\frac{G}{G_n}$$

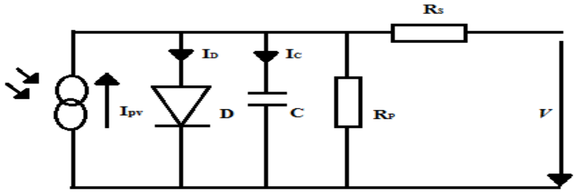

Fig. 2 Equivalent Circuit Diagram Of a Solar Cell

The mathematical model for the current Im shown in the following equation

$$I_m = I_{pv} - I_0[\frac{\exp(V + IR_s)}{aVt} - 1]$$

Where,

k - Boltzmann constant (1.3806 10-23 J/K)
T - Reference temperature of solar cell;
q - Elementary charge (1.602 1 10-19As);
V - Solar cell voltage (V);
I0 - saturation current of the diode (A);
Ipv- Photovoltaic current (A) [1].

D. Solar IV and PV Curve

A PV module has non-linear I-V (current-voltage) characteristics and its P-V (power-voltage) characteristics show that there is only one point where the module delivers maximum power as shown in fig. for extracting the maximum power from the cell the operating voltage and current should be corresponding to the maximum power point (P_{max})i.e. $V_m$and I_m respectively under a given solar radiation.

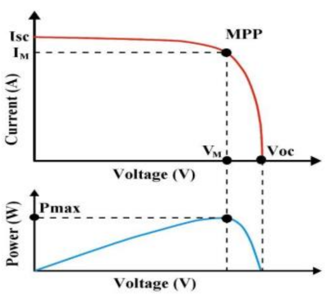

Fig.3 Solar IV and PV characteristics [20].

E. Grid-connected photovoltaic power system (grid interconnection)

A grid-connected PV power system is solar equipment which produces electricity and is connected to the utility grid. A grid-connected photovoltaic system consists of solar panels, one or several inverters, a power conditioning unit and grid connection equipment. A grid-connected system rarely includes an integrated battery solution, as they are still very expensive unlike, stand-alone power systems. When the situation is fine, the grid-connected PV system supplies the excess power, beyond consumption via connected load to the utility grid.

Reduction in the power bill is observed when electricity is generated by a grid-connected photovoltaic power system. These systems are maintenance-free and generate no pollution or noise. Increasing evidence suggests installing a PV system adds value to your property [27].

III. SYSTEM COMPONENTS

F. Solar PV Cell and Its Types

A solar cell is electrical equipment that converts the photonic energy directly into electricity by the photovoltaic effect, which is both a physical and chemical process. It is a form of photoelectric cell whose electrical characteristics such as current, voltage, or resistance, changes when exposed to light. Solar cells are the building units of photovoltaic modules, also known as solar panels.

A conventional PV module is formed by around 36/72 cells connected in series, enclosed in a structure, depending on its application and type of cell technology being used.

Their energy conversion efficiency varies between 10% to 15% for monocrystalline and 9% to 12% for polycrystalline cells. Among Film Cell technology, a-Si has 10%, CuInSe2 has 12%, and CdTe has 9%. Other novel technologies such as thin-layer silicon and dye-sensitized nanostructured materials are in the early development stage and have 9%. Among prominent Cell technology the monocrystalline PV Cell/module has the best efficiency among all commercially available technology [9].

B. Battery and State Of Charge Algorithm

The battery is an electrochemical device that converts chemical energy into electrical energy and electrical energy to chemical energy by oxidation-reduction reactions. Batteries of PV systems are frequently charged and discharged. Lead-acid battery with deep discharge is generally used for PV applications. For transportable applications Nickel—Cadmium or Ni—Metal hydride batteries are utilized. The batteries for PV applications are to be designed to meet the characteristics such as low cost, high energy efficiency, long lifetime, low maintenance, robust construction, Good reliability and less self-discharge and wide operating temperature, etc.

The only exception to controller need isthe battery is very large in comparison and the charging source is very small. PV arrays produce power only when illuminated, and it is, therefore, standard to employ, most commonly a series of rechargeable batteriesand a large energy storage mechanism. To prevent harmful battery overcharge and over-discharge conditions and to drive AC loads, a charge controller must be implemented. The primary objective is to optimize PV cells and energy storage and to increase overall system efficiency [26]. If a PV module produces 1.5% of the battery's capacity or less, then no charge control is needed. Therefore, the state of charge is providing for the proper distribution of power among inverter and battery [26].

Table 1: Algorithm for SOC[2].

State of charge (%)	Ratio between inverter and battery
If, soc ≥ 75%	Only Inverter
75%≤ soc ≤ 50%	Inverter (60%) +battery (40%)
25%≤ soc ≤ 50%	Inverter (40%) +battery (60%)

25% $\leq$ soc	Only battery

C. Inverter and Its Types

The Inverter is the power electronic device, which converts the DC voltage into AC. The DC source is normally an output of the controlled rectifier or a battery. The output voltage waveform of the inverter can be low distorted sine wave, quasi-square wave or square wave. The output voltage can be controlled with the help of drives of the switches. The pulse width modulation techniques are most commonly used to control the output voltage of inverters. Such inverters are called as PWM inverters. The output voltage of the inverter contains harmonics whenever it is not sinusoidal. These harmonics can be removed to an extent by using proper control plans. Inverters can be broadly classified into two types. They are Voltage Source Inverter (VSI) and Current Source Inverter (CSI). When the DC voltage is maintained constant, then it is known as Voltage Source (Fed) Inverter (VSI/VFI).When input current remains constant, then it is called Current Source Inverter (CSI) or Current Fed Inverter (CFI).

D. Controller

A controller is needed to prolong the battery life of your PV System. This becomesessentially important with sealed batteries where we cannotchange the water that is lost during overcharging.The most basic function of a controller is to prevent battery over charging. A controller will identify the battery voltage and reduce or stop the charging current accordingly when the voltage gets high enough.

E. Boost Converter

A Boost converter also known as step-up converter is a DC to DC power converter that steps up the voltage from its inputsupply. Therefore, the output current is lower than the source current. It is a case of switched mode power supply (SMPS) containing minimum two semiconductors, a diode and a transistor, and at least one energy storage element like a capacitor or an inductor or combination of both [2 and 34].

IV. SOLAR TRACKING AND DIFFERENT TYPES OF MAXIMUM POWER POINT TRACKING ALGORITHMS

G. Solar Tracking and Its Types

Principal of solar tracking system simplest method is to use LDR (Light dependent resister) for tracking system. Tracking is depending upon angle of incidence of solar light. If a fixed solar panel is mounted on ground level then sunlight will have an angle on incidence close to 0º. In progress to mid-day the angle of incidence is close to 90º, maximum power is achieved. This can be done by continuously tilting solar panel towards the sun which is called as solar tracking system. Solar Trackers have the potential to increase the output of solar panels by 20% to 30%. The choice of tracker type is dependent on parameters including installation size, electric rates, government incentives, land constraints, latitude and local weather. Some types of Solar Tracker are p**assive trackers, active trackers,** single **axis trackers and dual axis trackers.**

H. Different Types Of MPPT Techniques

The Maximum power point tracking (MPPT) is a technique used commonly with photovoltaic solar systems to maximize power extraction under all conditions. On the I-V curve, there is point where PVcell generates the maximum power as shown in fig. 3. This point always locates at the knee of the curve and it iscalled maximum power point. Since the power output of the PV cell is related with many parameters such solar radiation, temperature and load, the output characteristic is nonlinear. It isessential for the PV system to work at themaximum power point under varying external condition to achieve best performance. An MPPTis used for extracting maximum power from the PVcell and transferring that power to the load.

Many techniques of finding are MPP reported in literature. Few among them are listed here.

1. Constant voltage:- Constant voltage method is based on the observation that is the maximum power point is occurs between 72-78% of the open-circuit voltage Voc for the standard atmospheric condition. The solar PV module is always operated at this constant voltage. The duty ratio of the DC to DC convertor ascertains that the PV voltage is equal to:

$$V_M = K \times V_{OC}$$

where, K= 0.72 to 0.78

The method is simple, fast, and easy to implement but shows limited accuracy, Voc is required to be measured at regular interval and used only where temperature variation is little.

2. Constant current:- Constant current method based on the same phenomenon of the constant voltage method. The maximum power arrives in the range of 78% -92% of the short circuit current Isc.

$$I_M = K \times I_{SC}$$

where, K= 0.78 to 0.92

This method is simple, fast, and easy to implement, but less accurate. Isc must be measured at regular intervals.

3. Perturb and observe (P&O) or hill climbing: - Perturb and observe (P&O) method is basically an iterative approach in this method the operating point of solar PV oscillates around the maximum power point. This method is applied by perturbing the duty cycle at regular intervals. And oscillate around the point dP/dV=0i.e. MPP.

3.1 Hill climbing method:- Hill climbing and P&O method are two different methods with the same fundamental principle. P&O involves perturbation in terminal voltage to perform MPPT whereas the hill-climbing method involves perturbation in duty ratio (δ).

Table 2: Methodology of hill climbing method

Perturbation in terminal voltage	**Change in power**	**Next perturbation**
Positive	Positive	Positive (increment in duty ratio δ)
Positive	Negative	Negative (decrement in duty ratio δ)
Negative	Positive	Negative (decrement in duty ratio δ)
Negative	Negative	Positive (increment in duty ratio δ)

3.2 Beta method:- In this method a constant called beta (β) is given, the value of β is given by,

$$\beta = \ln I_{PV}/V_{PV} - \left(\frac{q}{k \times T \times \eta}\right)$$

where, k is Boltzmann's constant, η is diode quality factor, T is ambient temperature in Kelvin and q is electric charge.

This method is easy to implement, but slow and less accurate method whose operating point oscillates around MPP having an iterative approach. Solar characteristics are not required to be known earlier. Oscillation can be minimized by reducing perturbation step size which slows down the MPPT. Voltage and current both to be measured. Some modifications in P&O methods are Variable perturbation step size and Two-stage P&O tracking in which fast-tracking is obtained in the first stage and finer tracking in the second stage.

4. Incremental conductance (INC):- This method is based on the fact that slop of the PV array power curve is zero at the MPP (Pmax) this can be expressed as follows:

$$\text{Power } P = V \times I$$

$$\frac{dP}{dV} = I + V\frac{dI}{dV}$$

At true MPPT

$$\frac{dP}{dV} = 0$$

$$I + V\frac{dI}{dV} = 0$$

$$\frac{dI}{dV} = -\frac{I}{V}$$

where $\frac{dI}{dV}$ is incremental conductance.

In this method MPP is not exactly obtained, oscillation around the MPP. As compared to P&O more time required for computation also required extra circuitry hence complexity increased. Voltage and current both can be measured.

5. Pitot cell method:- In this method a pilot cell is used to calculate the open-circuit voltage instead of the whole PV array. After simple calculation array open-circuit voltage i.e. V_{Array} can be directly evaluated, this reduces the efforts of measuring Voc at regular interval i.e. calculated by

$$V_{REF} = K_3 \times V_{oc'pilot\ cell}$$

where, $K_3 \approx \text{constant} < 1$

6. Curve fitting method:- The characteristic of solar PV is non-linear, which can be modelled mathematically by using a curve fitting method. The nonlinear characteristic of a solar array can be approximated as:

$$P_{PV} = K_4V_{PV}^3 + K_5V_{PV}^2 + K_6V_{PV} + K_7$$

At maximum power point, $\frac{dP_{PV}}{dV_{PV}} = 0$

$$V_M = \frac{-K_5\sqrt{K_5^2 - 3K_4K_6}}{3K_4}$$

Where$K_4, K_5,\ K_6$and K_7 are constant.

7. System oscillations:- This method is based on the principle of maximum power transfer and based on comparing the ac component and the average value of the input voltage of the Power Conversion Stage to determine the duty cycle. At MPP the ratio of oscillation amplitude and average voltage is constant. In this method only voltage sensor is required and methodology is easy to implement.

8. dP/dVordP/dI feedback control method:- The power kept on increasing till the MPP and then decreases thereafter that with respect to voltage or current. In the context of the above this method compares two consecutive powers, but as compared to conventional methods, the magnitude of the slope is also considered to determine MPP. Three conditions are there:

Before MPP: $P_2 > P_1$

At MPP ::$P_2 = P_1$

After MPP ::$P_2 < P_1$

The following formula is used to determine the error in tracking and duty ratio is adjusted accordingly.

$$\in = K_c \int K_p \left(\frac{dP}{dI}\right) dt$$

9. Look up table method- In this method, the measured values of array's voltage and current are compared with previously stored values which harmonize the operating point of the array with respect to the maximum power point. The stored database contains different system condition for any insulation and temperature, and the corresponding maximum power point for specific solar PV array. The major disadvantage of this method is the requirement of bulk storage memory. Higher accuracy in tracking increases the number of operating conditions which requires more storage data. The tracking scheme is specific for array thus the implementation is complex, also considering all possible system conditions are both some to store and archive.

10. Ripple correlation control (RCC):- This method takes advantage of the signal ripple, which is automatically present in power converters. The ripple is interpreted as a deviation from which a rising gradient optimization can be realized. Oscillation in power provided through all-pass filter which makes use of ripples to perform MPP:

$$\frac{dI}{dt} \times \frac{dV}{dt} \text{ or } \frac{dP}{dt} \times \frac{dI}{dt} = 0$$

11. Current sweep method:- To obtain the I–V characteristic of the PV array, this method uses sweep waveform for the PV array current which is updated at a regular time interval. Also for each interval VMPP can then be calculated.

12. Temperature method:-Temperature based method:- In this method temperature of solar PV is measured. Changes

in MPP with respect to the temperature is obtained in the same way of the constant voltage method. The reference temperature with respect to MPP:

$$V_{MPP}(t) = V_{MPP}(T_{ref}) + T_{Kvoc}(T - T_{ref})$$

where $V_{MPP}$is the MPP voltage, T is the working panel temperature, $T_{Kvoc}$is the temperature coefficient of V_{MPP}, andT_{ref} is thestandard test conditions temperature. This method is easy to implement and required simple circuitry. The voltage and temperature of the PV array are required to be measured.

13.Load current or load voltage maximization method:-The method extracts the load parameter i.e. load voltage orload current to control the MPP instead of input current or voltage, Fig.4shows the schematic diagram of the method. MPPT power stage or a matching network has an internal controllable parameter proportional to V_{out} which controls the power flow in the network. This matching network may be a loss-free resistor or a transformer. The operating principle of this method is based on the single output parameter extraction, either voltage or current. By increasing output voltage or current, power output increases until the point of maximum power, thereafter power decreases with further increase in voltage or current. In this way the operating point will converge to the MPP.

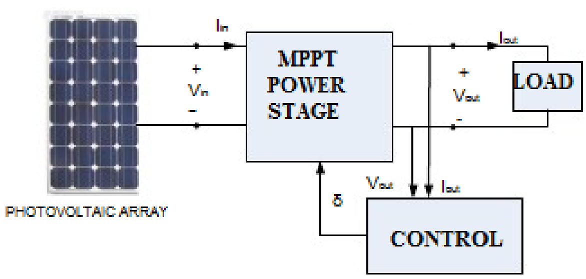

Fig. 4 Diagram of Load current or load voltage maximization method

14. Bisect search theorem (BST):-It is a mathematical approach to locate the roots of any functiony $= \mathrm{f(x)}$in an interval [a, b]. In the context of applying BST in MPPT thefunction is $\frac{\Delta P}{\Delta V}$in between the interval $[0, V_{oc}]$. As is obvious fromthe characteristic of a solar cell, it is a function which becomes zeroat MPP. Then the root represents the solution.

15.Some methods are also available which uses the optimization techniques such as variable step size incremental resistance (INR) method, parasitic capacitance method, one cycle control (OCC) method, slide control method, state space-based method, linear current control method, variable inductance method, analytic solution-based method, fuzzy logic control, Neural Network, Particle Swarm Optimization (PSO), etc. which gives excellent results[16-20].

I. Comparison of MPPT techniques

Comparison of MPPT methods is done on the basis of following factors such as Category, Dependency of PV array, Implementation methodology, Sensor required, Stages of energy conversion, Partial shading enabled, Grid interaction, Analog or Digital, Tracking efficiency, Tracking speed, Cost and Product available in the market. All methods have their own advantages and disadvantages. Some of the methods show highly effective results such as soft computing techniques but the methodologies used were complicated.

The methods which are simple in implementation such as constant voltage method, the constant current method, and the pilot cell method are less accurate. The Perturb and observe method is a commonly used method because its implementation circuitry is not complex, but it shows sluggish response where environmental conditions change rapidly. The beta method shows proficient results with fast change in insolation only if variation in temperature is less. Some methods are based on mathematical optimization algorithms to solve the non-linear problem such as state space-based method, analytic solution based and steepest descent, or gradient descent method [19].

V. POWER QUALITY AND HARMONICS

(a) Power Quality and Improvement Techniques:

Power quality is the integration of both voltage quality and current quality. Power quality is the set of limitations of electrical properties that permit electrical systems to function in their preconceived manner without significant loss of performance or life. The main issue are stationary and transient distortions in the line voltage such as harmonics, flicker, swells, sags, and voltage asymmetries. Power quality disturbances arise when certain deviations in magnitude and frequency of the power waveform beyond the specified range take place, creating problems for customers.

(b) Mitigation of PQ Problems:

There are two ways used to reduce the power quality problems, that is, first from the customer side and other from the utility side. Some ways can be load conditioning, which ascertains that equipment is less sensitive to power disturbances. The other solution can be to add a line conditioning system that suppresses or counteracts the power system disturbances. Several devices including flywheels, super-capacitors, other energy storage systems, constant voltage transformers, noise filter, isolation transformer, transient voltage surge suppressor, harmonic filters are used for the mitigation of specific PQ problems.

FACTS devices were designed to perform some tasks such as power flow control, voltage adjustment, reactive power compensation, transient and voltage stability improvement, transmission capability enhancement, power conditioning, power quality improvement, and interconnection of renewable and distributed generation and storages.

The impacts of FACTS devices occurred by switching, or controlled shunt compensation, series compensation or phase shift control. These devices work electrically as fast current, voltage or impedance controllers. The power electronics ensure noticeably short reaction times down to far below one second. FACTS device is used for long-distance AC transmission lines and the AC system performance. Moreover, FACTS can be in interconnected power system's technical problem solving.

The following FACTS devices were combined and made available: Static Var Compensator (SVC): Static Synchronous Series Compensator (SSSC);Static Synchronous Compensator(STATCOM); Thyristor Controlled Series Compensator (TCSC); Unified Power Flow Controller(UPFC); Dynamic Flow Controller (DFC); and Dynamic Power Flow Controller (DPFC).

STATCOM performs as a voltage controller and consequently improves system performance and increases grid Connectivity. Custom power devices like DSTATCOM, DVR are capable of mitigating multiple PQ problems associated with utility distribution and the end-user appliances. But the presence of harmonics is highly dangerous for both the connected loads & also for the power system connected to the grid due to harmonic current flow.

(c) Harmonics and Their Reduction Techniques

Harmonic distortion appears when the shape of the voltage or current waveform shifts away from the standard sinusoid. Harmonic distortion implies that higher-frequency components are also present in the power flow, apart from the standard power frequency component. These components can degrade equipment performance and may even cause damage to it. Some possible problems caused by harmonics are Increased heating effect on electrical distribution equipment and cables, Large neutral currents, Malfunction of protective devices like relays, overheating of transformers, Excessive voltage drops, Bus bar overloading, Losses in switching devices, etc.

(d) Harmonics Elimination

Harmonic filters separate harmonic currents to safeguard electrical equipment from damage due to harmonic voltage distortion. They can also help in improving the power factor. Conventionally, passive filters were used for harmonic mitigation, but due to certain drawbacks of the resonance due to matching with line impedance, they could compensate single harmonic at a time.

With further evolution of semiconductor devices, active harmonic filters with different current control strategies are being used extensively. Shunt Active filters can be formed from topologies like CSI and VSI, is used in active filters with many control schemes such as Hysteresis current control method, the synchronous frame of reference, direct control approach, fuzzy logic, dead beat control are used for PWM generation. Presently, active power filters are based on PWM converters and they connect to low and medium voltage distribution systems in parallel or in series. Harmonic Filter types include:

1. Passive filters: - Passive filters for harmonic reduction provide low impedance paths for current harmonics. Thus, the current harmonics pass through the shunt filters rather flowing back to supply.

2. Active filter: - Active filters are those which consist of active components like Thyristors, IGBTs, MOSFETs, etc. Active filters are predominantly present to compensate for the transient and harmonic components of load current i_L so that, only fundamental components stay in the grid current. The active filter makes use of power electronic switching to produce harmonic currents that counterbalance the harmonic currents from a nonlinear load.

3. Hybrid Filter: - Shunt active power filters operate as a controllable current source and series active power filters operates as a controllable voltage source. In order to compensate load current harmonics, series active power filters must operate simultaneously with shunt passive filters. This combination filter is generally called a hybrid filter. The SAF generates harmonic voltages to cancel the harmonic voltages produced by the non-linear load and the shunt passive filter eliminates harmonic currents generated by the non-linear load.

4. Inductively Active Filtering: - It includes PPF, APF, and HAPF methods. But, these methods are mainly used to implement the filtering and the reactive power compensation only at the PCC and cannot be able to provide an effective solution for the power-supply system connected with the network. To solve these problems, an inductive power filtering (IAF) method was put forward. This method can inhibit harmonic and reactive power components from flowing into the primary winding (grid) of the transformer, so it can effectively mitigate the Power Quality problems of the power-supply system [9 and 31-37].

VI. CONCLUSION

A Photovoltaic system consists of PV modules along with a good deal of power electronics as an interface between PV modules and load for both an effective and efficient utilization of naturally available solar energy. Solar PV modelling is based on the fundamental circuit equations of a solar PV cell taking into account the effects of physical and environmental parameters such as solar radiation and cell temperature. At the same time, the model can take into account the variation of the PV array output with solar irradiance incorporating the MPPT feature. This feature transfers the operating voltage of the model to its maximum power voltage for the maximum extraction of power from it.

The availability of bulk options as an MPPT makes its unambiguous selection, a tougher nut to crack. The comparative analysis provided in this paper may found that there are so many methods to obtain Maximum Power Point in solar PV. Some of them are discussed in this paper. The selection of the particular maximum power point tracking technique for a particular application is decided by those vitally important constraints. For example, the Perturb &Observe and IC are widely used where low cost is an essential factor. This evaluation of MPPT techniques helps in further research in the area of MPPT. The inverter keeps the AC output voltage at the specified level irrespective of solar irradiance E (W/m2). The models are developed for boost converters to maintain stable systems under various loads and resource conditions and also power quality and harmonics control methods are studied.

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