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STABILITY ANALYSIS USING SLIDING MODE CONTROLLER

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Abstract This report deals with control of a solar photovoltaic (PV) power generating system interfaced with the grid. A sliding mode control approach (SMC) is used for achieving maximum power tracking (MPT) control of solar-PV array. The Lyapunov function-based control approach is designed and modelled for the DC-AC inverter to serve the functions of an active power injection to the grid, balanced grid currents at unity power factor and load currents harmonics compensation. Proposed approaches eliminate the need of adjustment of system parameters under changing loads and generation scenario. The effectiveness of proposed control strategies is established using its stability analyses. The performance of solar-PV power generating system with proposed control algorithms is demonstrated using simulation and experimental studies under various operating conditions. Sliding Mode Controller algorithms have been presented for the boost converter and DC-AC inverter used for solar-PV power generating system array tied with the grid. Detailed design and stability analysis for both control approaches have been discussed to confirm its applicability under various operating conditions. The proposed approach has minimized the requirements of PI controller and only single PI controller is employed for DC bus voltage loop. The obtained simulation and experimental results have established that presented control approach performs satisfactorily under different operating conditions without adjusting the controller parameters.

1. INTRODUCTION

For the high performance motor control industrial standards we need four basic quadrant operation which contains field failing, speed regaining in load torque & the faster responses. But in this here are some problems are faced while operating like they require regular maintenance and the commutation needs. There are some limitation are also associated with the DC motor like lesser torque to weight ratio and the minimum unit capacity. Thus due to this the AC induction motors are usually adopted in industrial applications because they shows the much applications and advantages over the DC motor like they have simple structure, advanced torque to weight ratio & they have aptitude to work in worse environmental situations. But to control the AC motor is also a difficult task because we cannot access the rotor quantities which are the main factor for torque production. The DC machines are decoupling in relations of flux & torque. Thus there control is easier than the AC motors. Due to continuous development and the introduction of several new technologies like high switching frequency SC devices, micro controller & VLSI technology will provide the much effective control approaches.

1.1 Scalar Control

By name scalar control we can understand that this only shows the magnitude variation for the controlled variable only. For controlling a induction motor we need the variable voltage and the variable frequency power source. As due to the development of VSI and static voltage/hertz (V/f) control which are much simpler to use, and also economic and thus this is the most famous method for controlling the speed variation in induction motor effectively.

The main focus of this technology is to maintain the similar terminal voltage to frequency ratio thus it will provide the static flux over the larger range of speed variation. As the flux is taken to be constant here thus we have to maintain the full load torque capability here with in the constant static condition except the low speed. Thus by this control system machine concert will improved with in constant state and it given worst transient response. And the Constant Volt/Hz control will kept stator flux constant and did not manage the decouple within the flux and torque component. Thus to ignore the open loop speed variations in load torque & the supply voltage [1].

The Scalar control drive is mostly used in the industrial applications on large scale because they are much convenient to implement. That will give birth to the slower response and thus due to this the system is goes unstable. As in modern application the use of scalar control devices is almost diminished because no days there are several advanced vector control devices are available which will gives the much higher performance

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1.2 Vector Control

When we divide stator current into 2 different orthogonal components, in which first component is way of flux linkage, which shows the magnetizing current & this component is at the right angle with the flux component and shows the torque component of current, and then if we vary these component independently then the induction motor can be used as the distinctly excited DC motor. This idea was first implemented in early 1970s. thus for implementing vector control we need the very precise information about the magnitude. Thus on basis of method for the acquisition of the flux information, we can define the vector control method as: direct or indirect. In the first method which is direct method we strictly need to measure the position of flux to which we need the orientation, or we need the estimation from the machine terminal variable like the speed. Thus flux which we measure here is utilized for feedback loop and thus due to this machine constraints are having the lesser effect over the overall drive performance. But to measure the flux by using the sensor we need the special manufacturing process. [1].

As in the research there are some indirect method are also proposed [2], which will completely eliminate the direct measurement of rotor flux, but here we can manage the flux position by adding rotor position signal along. the accurate rotor speed data and also about the targeted slip position thus by this we can compute the model of induction motor, in which we again needs the machine parameters that varied with the frequency, temperature and the magnetic saturation. Thus due to this there are several adaption methods has been proposed in literature studies. While performing this it has also been noticed that the controller performance is not perfect among the normal operating temperatures generally in the high performance applications and thus these parameter adaption method are generally important in the case of important applications.

2 SLIDING MODE CONTROLLER

We can use this method when there is modeling disturbances, variation in parameters, which will facilitate that the upper boundary of the absolute value is not known. Such kind of modeling inaccuracies will cause due to the changes in plant parameters, or by choosing the simple representation of system dynamics. Thus the sliding mode controller technique will provide the satisfactory solution to maintain the stability in presence of modeling parameters. Generally this method is best for the tracking the motor controls, the robotic manipulators which changes the mechanical load in a wide range. Thus here we use the induction motor as the actuator which has the very complex trajectories.

Soto and Yeung [3] and Utkin [4] present a study in which he applied the sliding mode control technique to induction motor drive. Thus in the study the sliding model control technique is used for the indirect vector measured induction machine to control the speed and position. It is used in the anther study where is used t control the position loop for the indirect control induction motor drive and did not uses any rotor resistance identification method. Thus in such cases the motor flux and the speed is control by the sliding mode controllers which having variable switch gain. Thus in the study we present the sliding mode controller with rotor flux in case of induction motors. Here we also estimate the rotor flux by using the sliding mode observations.

As there are several estimation algorithms and the sensor less schemes are develop in some last year due to the continuous development in this field, thus this proposes the simple, effective and lower estimation of sensitivity scheme for the lower power induction motor drives si not being that much explored. Thus to answer such kind of problems the sliding mode controller technique is the best technique. As in practical all the parameters are being affected due to uncertainty cause due to modeling error and presence of external disturbances.

While designing a sliding mode controller we generally have two steps (1) designing a sliding surface on the basis of required close loop performance and (2) to design a suitable control law. Thus here to eliminate the non-robust reaching phase we propose an integral sliding mode in literature [19, 20] which will permit the SMC to combine with the other techniques. Thus following are the main advantage of SMC:

1. While sliding mode the system is not able to match with the model uncertainty and the disturbances
2. In the case when the system is not a sliding manifold than in this case it will act as reduced order system w. r. t. original plant. As on basis of claimed robustness the practical implementation of SmC is not being performed by the major limitation which is known as chattering, this is a high frequency bang-bang type control action. The main reason behind the chattering is fast dynamics which we generally ignore in the ideal model of sliding mode, thus this control is assumed to switch the indefinite frequencies. As in real plants because of inertia of actuators and sensor as well as occurrence dissimilarities, the switching is performed with the high and definite frequencies. Thus due to this the main drawback is that the skidding mode will be performed only in the smaller region of sliding manifold,, which dimension is inverse of the control switch frequency. As while sliding mode because of the finite switching of the control signal the states will be switched about the sliding surface other then sliding directly over it. This kind of switching will also be performed over the higher frequencies and also knows as chattering.

4. SIMULINK MODEL

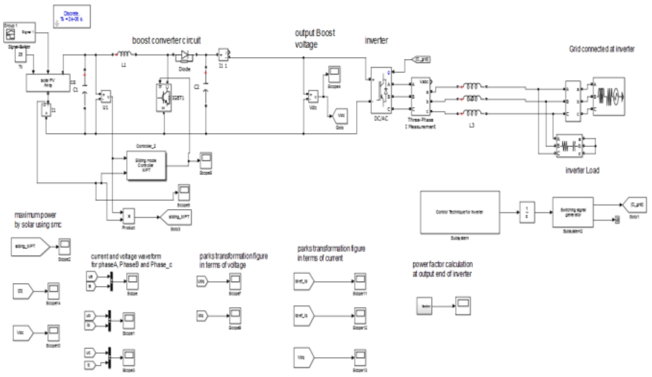

Fig 1 Proposed Simulink Model

Proposed Simulink Model is represented in Fig 1. The proposed model having boost converter, grid inverter & other different component. The power factor calculator is also used at the output end of inverter

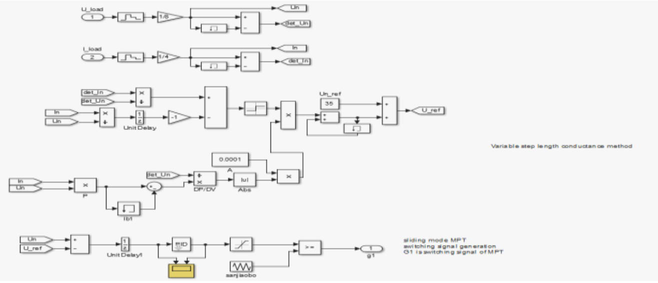

Fig 2 Sliding Mode Controller

The Sliding Mode controller is used in the proposed model for switching signal generation. The PID Controller is used to design the SMC

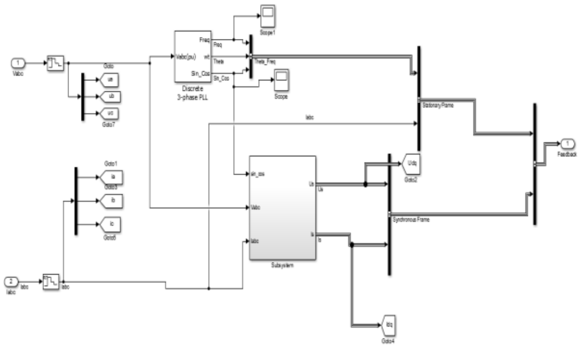

Fig 3 Subsystem of the block

The internal sub-block is defined in fig 3 .Phase locked loop is described in this block. In accordance to that block output is given to secondary frame and the sub frame.

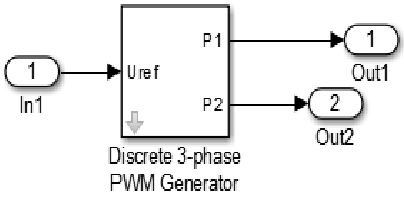

Fig 4 Switching Signal Generator

Switching Signal Generator is represented in fig 4. In this there are two output signal & one input signal in which discrete 3 phase PWM is applied.

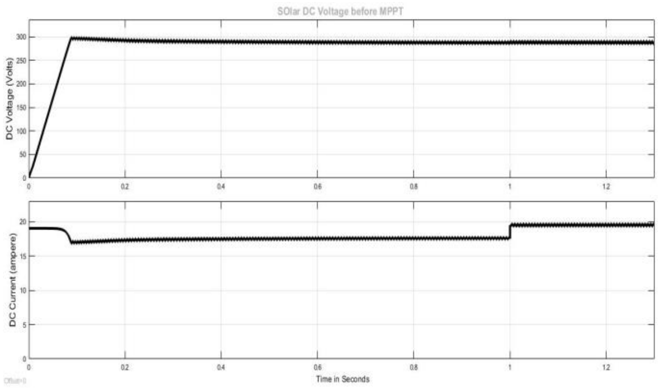

Fig 5 Solar DC voltage and Current before using sliding mode MPPT

Solar DC voltage and current before sliding mode MPPT is defined in fig 5. In the1st graph Dc voltage is increase linearly with respect to time. It is increase with time up to 0.1 sec then voltage become constant to 295 V. Similarly DC Current gives flat portion 0.1 sec to 1 sec. As Pv panels produce current when 2 layers of silicone are "doped" to encourage the movement of electrons. All that is required is an extra push as it were, provided by a few trillion photons from the sun, that bombards the silicone and add enough energy to the electrons so that they can jump over to the other layer. The output of solar panel is a DC because sun light falling on solar panel is continues. So the energy generation or conversion is also continues. Hence voltage produce due sun energy by solar panel is continues like DC energy or DC voltage. To begin with we will definitely notice that in case of a DC power system it has the advantage of avoiding the DC to AC conversion losses. This also reduces the cost of any kind of inverter circuit or inversion technology. But usually DC based systems can operate only on lower standard DC voltages such as 6v, 12v, 24v, 48v.The DC systems are usually based on these voltages because of the availability of batteries in the market. Since batteries are only available in 6v or 12v voltages, hence, it is common to either choose a 6v system or a voltage system which is a multiple of 12v.In solar DC Voltage and DC Current before sliding mode,

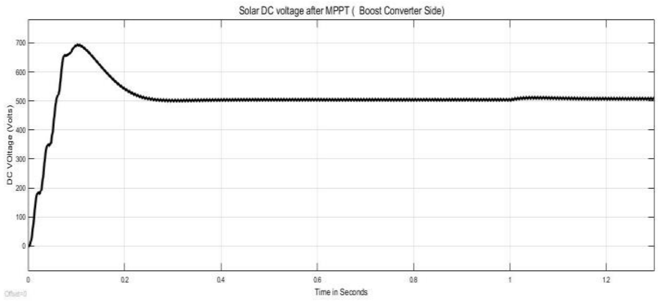

Figure 6 Solar DC Voltage Using Sliding Mode MPPT

Solar Dc Voltage using sliding mode MPPT is shown in fig 6. The graph is increases upto 0.1 sec then it will be decreases then become constant 5000v after 0.3 sec.The major principle of MPPT is to extract the maximum available power from PV module by making them operate at the most efficient voltage (maximum power point). That is to say: MPPT checks output of PV module, compares it to battery voltage then fixes what is the best power that PV module can produce to charge the battery and converts it to the best voltage to get maximum current into battery. It can also supply power to a DC load, which is connected directly to the battery. A MPPT **solar charge controller** is the charge controller embedded with MPPT algorithm to maximize the amount of current going into the battery from PV module. MPPT is DC to DC converter which operates by taking DC input from PV module, changing it to AC and converting it back to a different DC voltage and current to exactly match the PV module to the battery. MPPT algorithm can be applied to both of them depending on system design. Normally, for battery system voltage is equal or less than 48 V, buck converter is useful. On the other hand, if battery system voltage is greater than 48 V, boost converter should be chosen. MPPT solar charge controllers are useful for off-grid solar power systems such as stand-alone solar power system, solar home system and solar water pump system, etc. In any applications which PV module is energy source, MPPT **solar charge controller** is used to correct for detecting the variations in the current-voltage characteristics of **solar cell** and shown by I-V curve. MPPT **solar charge controller** is necessary for any solar power systems need to extract maximum power from PV module; it forces PV module to operate at voltage close to maximum power point to draw maximum available power.

MPPT **solar charge controller** allows users to use PV module with a higher voltage output than operating voltage of battery system.

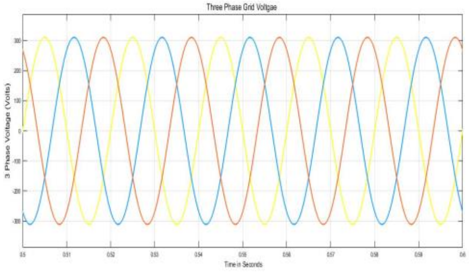

Figure 7 Three phase Grid Voltage 50 Hz Voltage magnitude 300 Volts

Three phase grid voltage is represented in fig 7. The amplitude of three phase voltage is 300 V. Three voltages are aligned by 120 degree phase angle. The three-phase power is mainly used for generation, transmission and distribution of electrical power because of their superiority. It is more economical as compared to single-phase power and requires three live conductors for power supply. In a 3 phase system, there are three equal voltages or EMFs of the same frequency having a phase difference of 120 degrees. These voltages can be produced by a three-phase AC generator having three identical windings displaced apart from each other by 120 degrees electrical. When these windings are kept stationary, and the magnetic field is rotated as shown in the figure 5.7 above or when the windings are kept stationary, and the magnetic field is rotated as shown below in figure B, an emf is induced in each winding. The magnitude and frequency of these EMFs are the same but are displaced apart from one another by an angle of 120 degrees

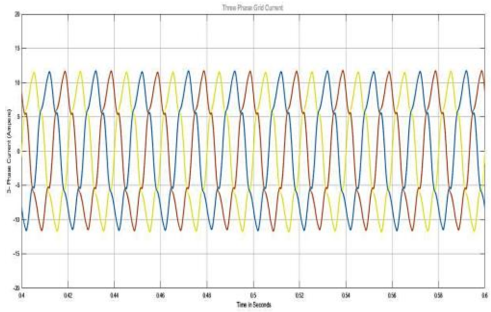

Figure 8 Three Phase Grid Current 50 Hz

3 phase grid current is shown in fig 5.8. The amplitude of grid current is 12 ampere. The time is varied for 6 sec. It shows the basic idea of a modified dual-stage inverter. The DC-AC stage performs the MPPT through the P and O method to maximize the direct axis current, I_d, required for the grid current control. Grid current I_d reacts the active power delivered by the photovoltaic array and is expressed through the inverter modeling, using the Park transformation [59, 60].Then, the inverter output power is maximized without additional sensors. In a single-stage inverter, this principle can also be used. Figure 9 presents the proposal topology for the dual-stage inverter in a three-phase configuration. In both cases, specific measurements for MPPT are made. In the proposed grid-connected dual-stage inverter, the direct axis current, I_d, is observed, which serves for the inverter stage to set VVdc. These actions define the DC-DC converter's input characteristic behavior, which determines the PV array operation point. When I_d is maximized, the PV array operates on MPOP. As noted, the variables used in the MPPT are I_d and Vdc, initially employed in the grid current control, that is, any specific measurement for MPPT's purpose is made.

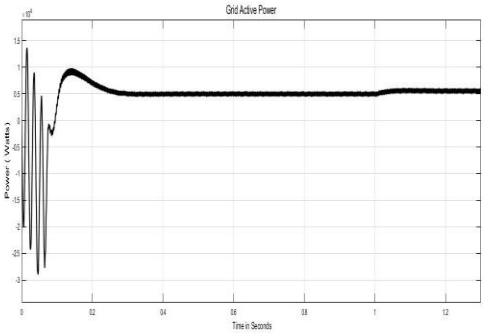

Figure 9 Grid Active Power

Grid active power is shown in fig 9. Initially up to 0.1 sec the power is fluctuated & then it will become constant. Constant Power is 0.5 watt from 1 sec to 1.25 sec.In the utility grid, current and voltage have a sinusoidal progression, meaning that their product, electrical power, is also sinusoidal. In DC systems, the sign of the power indicates the direction in which the electrical energy, in the form of active power, is transported.

grid connected mode. Here, $v_{a,b,c}$ and $i_{a,b,c}$ are the inverter output voltages and output currents. Inverter control system consists of power control using the instantaneous active power and the instantaneous reactive power and current control at grid connected mode. Instantaneous active and reactive powers p and q are determined by v and i in the d and q axes and using a dq transformation. i_{dref} and i_{qref} are determined from deviation of p and p_{ref}, q and q_{ref}, respectively, through PI control. Further PI control is executed in current control. In addition, a non interacting control must be adopted in there. For an AC resistive circuit, the current and voltage are in-phase and the power at any instant can be found by multiplying the voltage by the current at that instant, and because of this "in-phase" relationship, the rms values can be used to find the equivalent DC power or heating effect.

However, if the circuit contains reactive components, the voltage and current waveforms will be "out-of-phase" by some amount determined by the circuits phase angle. If the phase angle between the voltage and the current is at its maximum of 90°, the volt-amp product will have equal positive and negative values.

In other words, the reactive circuit returns as much power to the supply as it consumes resulting in the average power consumed by the circuit being zero, as the same amount of energy keeps flowing alternately from source to the load and back from load to source.

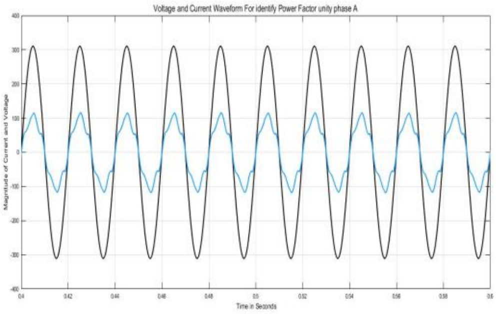

Figure 10 Phase A Load Current and Voltage shows zero phase difference between Current and Voltage

Phase A Load Current and Voltage shows zero phase difference between Current and Voltage is shown in fig 5.10. Voltage is varied from -300 to 300 V. Current is varied from -100 ampere to 100 ampere.

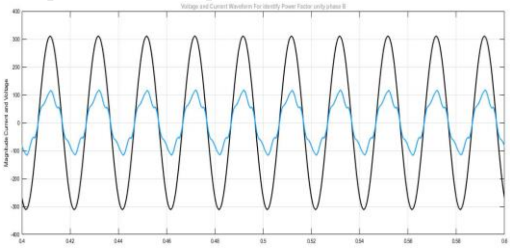

Figure 11 Phase B Load Current and Voltage shows zero phase difference between Current and Voltage

Phase B Load Current and Voltage shows zero phase difference between Current and Voltage is shown in fig 11. Voltage is varied from -305 to 305 V. Current is varied from -105 ampere to 105 ampere.

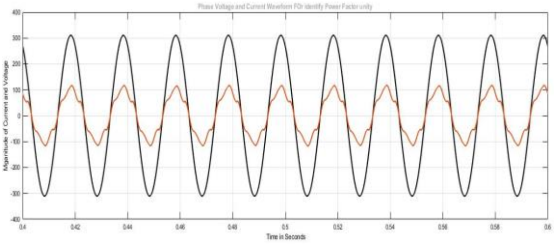

Figure 12 Phase C Load Current and Voltage shows zero phase difference between Current and Voltage

Phase C Load Current and Voltage shows zero phase difference between Current and Voltage is shown in fig 12. Voltage is varied from -250 to 250 V. Current is varied from -100 ampere to 100 ampere.

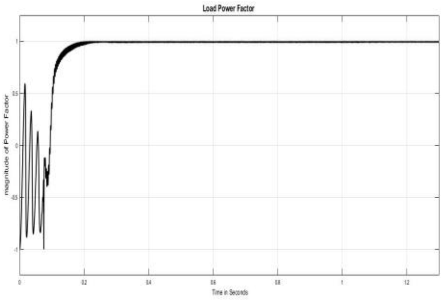

Figure 13 Load Power Factor by control technique

Magnitude of Power factor is shown in the fig 13. Initially the power factor is floated but after 0.2 sec it will become stable for whole time period. In AC circuits, the power factor is the ratio of the real power that is used to do work and the apparent power that is supplied to the circuit. Power factor (PF) is the ratio of working power, measured in kilowatts (kW), to apparent power, measured in kilovolt amperes (kVA). Apparent power, also known as demand, is the measure of the amount of power used to run machinery and equipment during a certain period. The power factor can get values in the range from 0 to 1.When all the power is reactive power with no real power (usually inductive load) - the power factor is 0.When all the power is real power with no reactive power (resistive load) - the power factor is 1.Power factor correction is an adjustment of the electrical circuit in order to change the power factor near 1.Power factor near 1 will reduce the reactive power in the circuit and most of the power in the circuit will be real power. This will also reduce power lines losses. The power factor correction is usually done by adding capacitors to the load circuit, when the circuit has inductive components, like an electric motor.

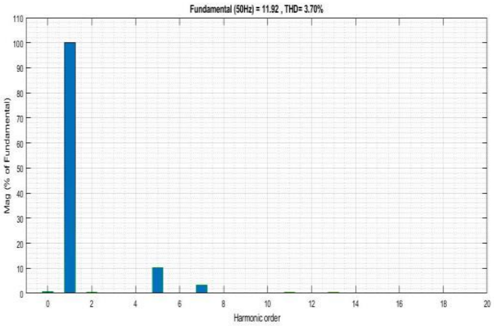

Figure 14 Load Current Total Harmonics 5th and 7th is presents

Total fundamental is 11.92 at 50 Hz frequency. Total harmonic distortion is achieved up to 3.70 % as compared to previous work. Total harmonics of 5^{th}& 7^{th} present in load current. Total harmonic distortion, or THD is a common measurement of the level of harmonic distortion present in power systems. THD can be related to either current harmonics or voltage harmonics, and it is defined as the ratio of total harmonics to the value at fundamental frequency times 100%.The following calculator computes the total harmonic current distortion (THD), Peak Current, RMS

Current, and Crest Factor based on individual harmonic current distortion values between the 1st and the 50th harmonic. Input the fundamental current and individual harmonic currents to compute THD also to view a waveform plot based on the input values. The waveform plot assumes all phase angles for individual current distortion values to be zero degrees (in phase with the fundamental current).When inputting the data, be sure to use consistent units of Amps, or Per Unit Amps. Total Harmonic Current Distortion (THDC) of a current signal is a measurement of the harmonic distortion present and is defined as the ratio of the sum of the power of all harmonic current components to the power of the fundamental frequency current. THD is used to characterize the power quality of electric power load and the current flowing in your system's conductors. Distortion factor is a closely related term and is sometimes used as a substitute term.

5. CONCLUSION

In this theory we explain about the sliding mode controller in brief. Here we also identify the equation of induction motor control so that we can use them in our control techniques. Thus here we design the controller gain and the bandwidth by taking the several factors like rotor resistance variation, model in accuracies, and also to have an ideal speed tracking. Here we consider the case of load disturbance, and module the responses of SMC to get the satisfactory performance. This system also provides the better trajectory tracking performance. The final conclusion for this present model is as follows:

1. Minimum ripple in solar PV model DC current and Voltage by using Sliding mode controller
2. The sliding mode controller based MPPT technique boost the voltage up to 500 volts which is ripple free
3. Track maximum power in solar PV mode
4. MPPT Controlled algorithm is Sliding mode controller
5. Voltage source inverter is controlled by Space vector pulse width modulation and having two control loop
    (a) Inner current control loop which is used to Reduce total harmonics distortion up to 3%
    (b) Outer voltage loop is used to attain unity power factor
6. Total harmonics distribution is 3 % in 3 phase AC Load Current
7. Power factor is unity
8. 2 KHz switching frequency of SVPWM in Voltage source inverter very less power device loss

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