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Design of Harmonic Filters for Photovoltaic Energy Applications

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ABSTRACT— the main idea behind this paper is to extract maximum power from solar photovoltaic system by using LMS filter technique and also to reduce the harmonics in five phase inverter drive by using single tuned filter technique to increase the efficiency and smooth operation of the motor. Harmonics are usually generated in the system because of non-linearities present in the load as well as the components such as transformer, relay circuits, connected switches, capacitor, high inductive load used for industrial applications etc. which in turn leads to reduction in power factor, drop in the voltage and heat losses. Therefore a suitable model is implemented in Matlab/Simulink by the combination of Single Tuned Filter and LMS filter which helps to extract the maximum power on the generation side and also to improve the performance analysis of five phase inverter before using it for industrial load.

Keywords— MPPT, PV, Solar, Five-Phase, harmonics, inverter drive, filters, single tuned filter

I. INTRODUCTION

The industrial demand of the electricity has been increasing enormously day by day in order to fulfill the requirement of the load. Various non-conventional methods have been used to meet that requirement such as solar photovoltaic system, wind energy, tidal energy and energy which is produced from the urban waste. Amongst all solar energy is most reliable, efficient method of generating electricity for industrial applications, household purposes, hot water etc. Unlike other energy sources solar energy is available until we are having sun in the atmosphere. But the disadvantage about the solar photovoltaic system is high initial cost and low efficiency, so we need to extract maximum power from solar arrays. Therefore in order to extract the maximum power from solar photovoltaic system various techniques have been implemented such as Particle Swarm Optimization method [1], Artificial Bee Colony method [2], Fuzzy logic [3], Artificial Neural Network [4], Cuckoo search method [5] etc. The above techniques having numerous advantages such as how to overcome from various environmental conditions, effect of partial shading and changes in the irradiance. But because of the complexity in the design, higher initial cost, complexity in algorithm implementation, slow speed for tracking, these methods are still in observation under the eyes of various researchers in order to overcome the drawbacks of these methods.

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So the researchers once again take into consideration the conventional MPPT techniques like Hill climbing [6], perturb & Observe [7] , Incremental Conduction [8] Amongst all the above methods which is used to track the maximum power point. P&O is the easiest, simpler and having a very fast convergence speed. But it tends to the oscillations around the MPP that cause the system energy losses Induction motors nowadays finding a numerous advantages in the industrial applications. With the advent in the technology various designs in the motor drive has come into the picture according to customer specifications [8].The current circumstances predicted that the three phase motors regularly used for industrial applications purposes in whole world. But three phase induction motors has lower rotor speed, poor electromagnetic torque, higher harmonic spectrum, poor torque speed characteristics. Therefore to overcome all these limitations number of phases in the motor should need to be increased. With increase in the number of phases the advantages also tends to increase in the system [9]. That's why nowadays many researchers try to go for five phase induction motor for industrial purposes.
All the problems which are generally occurred in the inverter drive is just because of harmonics. Harmonics tends to produce distortion in the voltage waveform and current waveform. Inverters are generally made up of switches; therefore during switching period there will be an introduction of odd harmonics which affects the performance of the system, power factor reduction, burden on the generator to fulfill the load demand and heat losses. That is the reason many researchers are trying to work on the new innovations in order to suppress the affect of harmonics. Various filter designs have been introduced to overcome the affect of harmonics which is present in the inverter. In Five Phase inverter there is no effect of 5th order harmonics and also the multiples of it which is itself an advantageous thing for industrial applications [10]. Now our main concern is just to eliminate the effect of harmonics before using it for industrial load. So according to the above literature survey we need to design an algorithm based on P&O technique to extract the MPP in efficient and reliable way and also requirement for passive filter is there to suppress the odd order Harmonic in Five Phase inverters.

II. PV MODELING

There are lots of PV models in the market but the most precise and accurate model is the 2 diode PV model. R_P and R_s are the parameter of 2 diode model Photovoltaic panel which helps the MATLAB software for computational of the other parameters performance [11]. To analyze the 2 diode models the figure.1is taken into consideration. The output current of the Solar cell can be written as:

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$$I = I_{PV} - I_{d1} - I_{d2} - \frac{V + IR_s}{R_p} \qquad (1)$$

Rs and Rp are the series and parallel Resistance respectively. The thermal voltage of the diode is V_T. Diode's thermal voltage is V_T. The formed current by lights is (I_{PV})

$$I_{PV} = (I_{PV-STC} + K_I(T - T_{STC}))\frac{G}{G_{STC}} \qquad (2)$$

I_{PV_STC} is computed in the standard test condition (STC), i.e., irradiance G = 1000 W/m^2 and temperature T = 298 K (25°C). The coefficient of the short circuit current (I_{SC}) is K_I. Diode's saturation current is specified by:

$$I_{d1} = I_{d2} = \frac{I_{SC-STC} + K_1(T - T_{STC})}{\exp((V_{OC-STC} + K_V(T - T_{STC}))/V_T) - 1} \qquad (3)$$

In (3), I_{SC_STC} is the short circuit current and V_{OC_STC} is the open circuit voltage in standard test condition (STC). K_V is the temperature factor of the voltage.

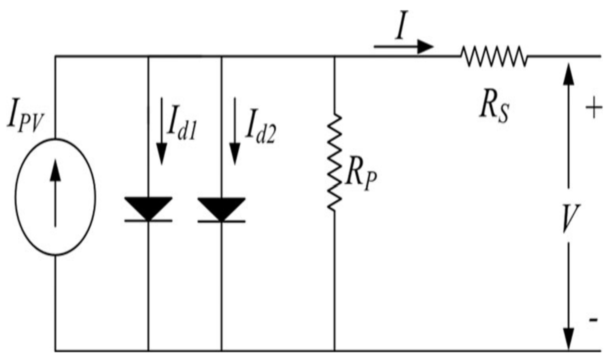

Fig.1: The 2-diode model of photovoltaic cells.

III. P&O-BASED LMS MPP TRACKER

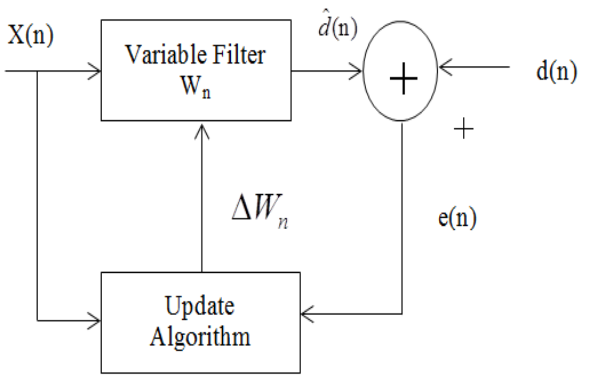

Fig.2: Adaptive FIR Filter's block diagram

An adaptive filter is that filter which has capability to regulate its work accordingly defined by a process called optimization. By looking into the complexity of various algorithms for optimization, digital filters are also called as adaptive filters that are generally used to implement the digital signal processing (DSP) and are having inherent characteristics to correct the signals once it is applied to the filter. In terms of comparison, a non-adaptive filter is having various stationary factors (that mutually custom the transfer functions)

A. The execution of the adaptive filter by means of LMS termed as least mean square technique

The event of LMS are generally belongs to a sitting of the adaptive filter which is generally applicable to reproduce a suitable filter thereby defining the factors of the filter that describes how to create LMS for error signals [12].

B. Least Mean Square (LMS) Algorithm

From several times, a well known adaptive filter is generally used as a functional device in order to examine the signals. Let us consider adaptive filter which is having a length for an instance L. This arrangement is generally produced an output vector y(n) for an input signal x(n) which is written in the following equation.

$$y(n) = x(n)\,T\,w(n) = w(n)T\,x(n) \qquad (4)$$

In order to specify least mean square algorithm, weight vector should need to be updated which is represented in the following equation;

$$w(n+1) = w(n) + \mu\, x(n)\; e(n) \qquad (5)$$

Where μ generally denotes the step size

In order to track the maximum power a complete photovoltaic MPP system is considered which is displayed in figure 3. Because of the large number of variation in the temperature as well as in irradiance of solar energy, it is impossible to apply voltage as well as current in a straightforward way to various units which stores the energy. Firstly, these should need to be apply to a controller device so that maximum power can be tracked for the existing currents as well as voltages in a manner that unit which stores the energy made up of inductance as well as capacitance circuit should grasp the additional power which is generated in the earlier cycles and whenever there is a less production of the power in earlier cycles it should need to donate it. This switching time should need to be provided by the power electronics device such as MOSFET as well as IGBT switches to a circuit which is made up of LC by using a control unit called MPPT. This circuit and switching devices generally consists of buck boost converter which works on the mechanism of DC-DC level of conversion. Only the current values and the readings which has been taken previously are in use, in existing technique of perturb-observe method without doing any kind of consideration in the future values of the power. The methodology which is proposed here, a predictive power is generated which can be further optimized by using a suitable algorithm termed as least mean square in order to uphold the best possible highest point of power. The flowchart which is given below, p(n+1) represents the predictive power. [13].

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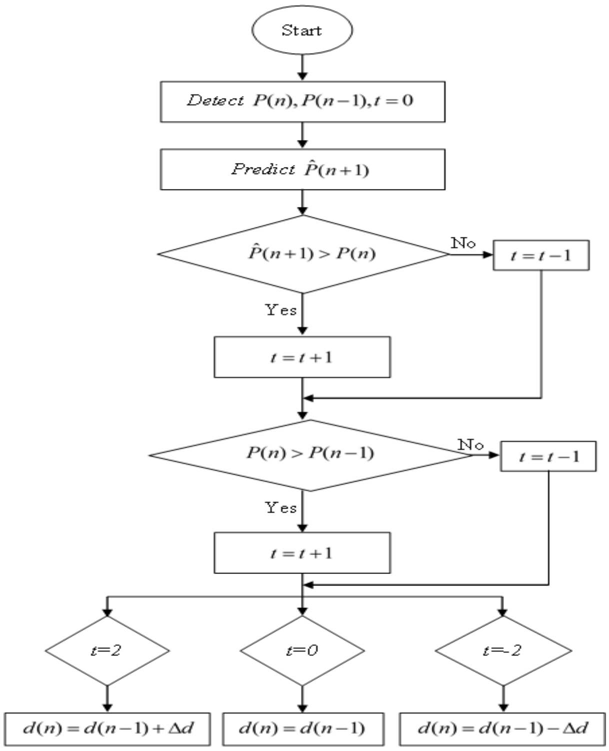

Fig.3: Flowchart LMS based predictive power MPPT algorithm

IV. Simulation Results of Photovoltaic System

For an array consists of 42 series modules and 11 parallel modules simulation results are carried out. User defined attributes of module used are as follows. Open circuit voltage Voc= 40V, Isc=28.8A, Voltage at MPP Vmp(v)=34, ,current at MPP Impp=26.6A, cells per module= 10 Fig. 4 shows the I-V & P-V curves of array while it works at optimum conditions. Fig.5 represents the PV power waveforms using conventional P&O technique and least mean square technique. The performance of LMS based MPPT algorithm has been evaluated at 1000 W/m^2 and 25^o temperature. The output power by both methods is tabulated in Table 1.

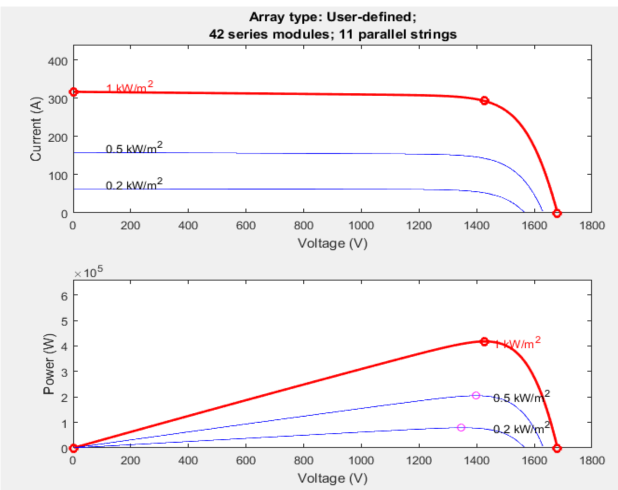

Fig. 4: I-V & P-V curves of array in optimum conditions

TABLE 1: For Different Simulation Time the Output Power Array Based On LMS Filtration and P&O

Time in sec	Array-power (KW) LMS method	Array-power (KW) PO method
0.002	34.5	13.5
0.008	31.5	25.6
0.14	24.2	21.7
0.149	275	209
0.16	308	211
0.165	337	224
0.169	372	248
0.171	393	284
0.175	398	324
0.179	385	366
0.282	397	396
0.286	399	399
0.3	400	395
0.4	410	398
0.5	420	398.8
1	430	398
1.5	430	398
2	430	398

From the comparison in table 1 we can conclude that the LMS filtration technique achieves the peak faster and more stable and reliable than conventional P&O technique. In this work, DC-DC Boost converter is used to boost up the DC voltage and a MOSFET switch is used to turn ON and OFF the output power.

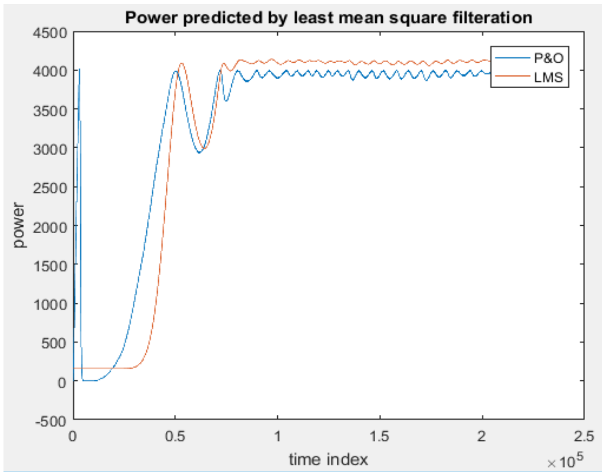

Fig.5: Output power Comparison of Perturb-Observe and LMS based MPPT tracking

From the Fig.7 it's found that least mean filtration gives power with least fluctuation variance and tends to achieve stability in peak value faster than P&O technique.

V. Design and Implementation of single tuned filter

To design single tuned filter the Quality factor is the main parameter to be considered.

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$$Q = \frac{\sqrt{\frac{L}{C}}}{R} \qquad (5)$$

Whereas R is the resistance for tuning, Q is the quality factor and L & C are the Inductance and Capacitance for tuning respectively.During design of single tuned filter the inductive reactance X_L and capacitive reactance X_C must be equal to achieve the resonance.

$$X_C = X_L \qquad (6)$$

$$X_C = \frac{1}{\omega C} \text{ and } X_L = \omega L \text{ , where } \omega = 2\pi f$$

F is the fundamental Frequency

VI. Five Phase Inverter and Induction Motor

10 IGBT switches are used to make up five phase inverter as presented in fig.1. Pulse generator P1-P10 generates five phase signals, each IGBT switches is turned on for 180^0 mode of conductions with 72^0 phases out with each phase. By appropriate switching of the IGBTs output voltage of inverter can be achieved.

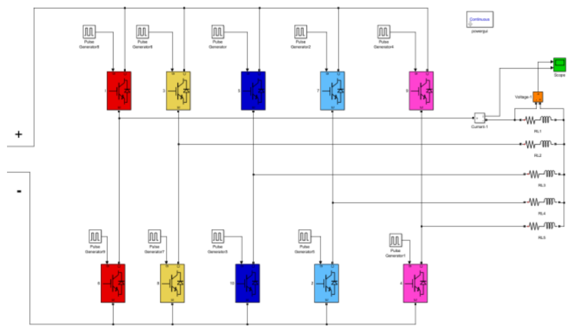

Fig.6. five phase along with 5 phase induction motor

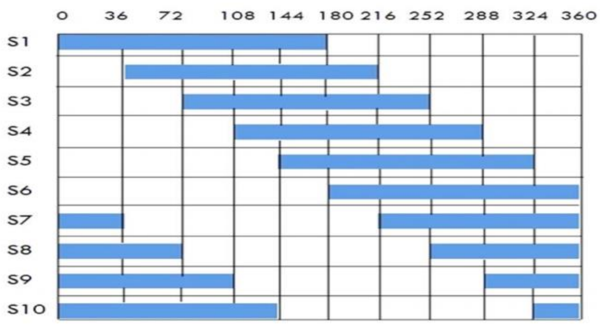

Fig.7. IGBT switching sequences

For 180^0 conduction mode 2 IGBT from up and 3 IGBT from down side must be on or 3 IGBT from up and 2 IGBT from down side. IGBT based inverter switching sequences are represented in Fig.7.

VII. Five Phase Inverter and Induction Motor with Single Tuned Filter

Single tuned passive filter is linked between the output of five phase inverter and input of the five phase induction motor as displayed in Fig.8. The designed values for single tuned filter are: C=23µF, L=858mH, R=100 Ω

Table.2Expermental values used for RLC

Apparatus	Range
Resistor R1 to R5	100 Ω
Capacitor C1 to C5	23µF
Inductor L1 to L5	858mH

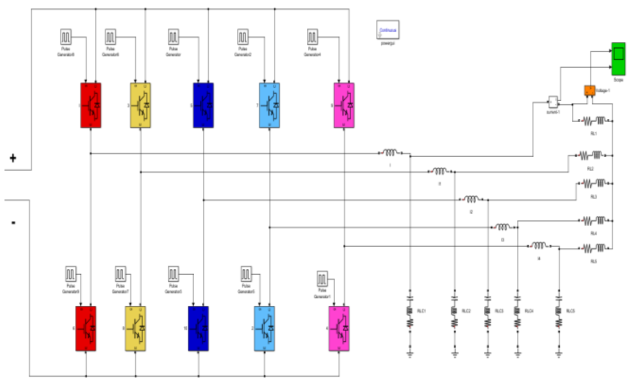

Fig.8. Single tuned filter connected to the output of five phase inverter along with 5 phase induction motor

VIII. Results of Simulation for Five-Phase Inverter along with 5 Phase Induction Motor

For rated speed application of 50Hz simulation have been carried out, with the resistive inductive load of R=2 Ω and L=1.4mH. The measurement and plotting of phase output current and voltage without and with single tuned filter for five phase induction motor along with PWM inverter has been done. Evaluation of THD with and without tuned filter has been carried out for five phase inverter drive.

The phase voltage and current waveforms for an input frequency of 50Hz for Five induction motor along with PWM Inverter has been plotted in Fig.9. Phase voltage and current waveforms of five phase induction motor with PWM inverter along with single tuned filter has been plotted in Fig.10.THD evaluation with and without single tuned filter have been done for Five phase PWM inverter.

Fast Fourier Transform (FFT) analysis carried for both with and without single tune filter in five phase PWM inverter drives. And these analyses are displayed in Fig.11 & Fig.12 correspondingly.

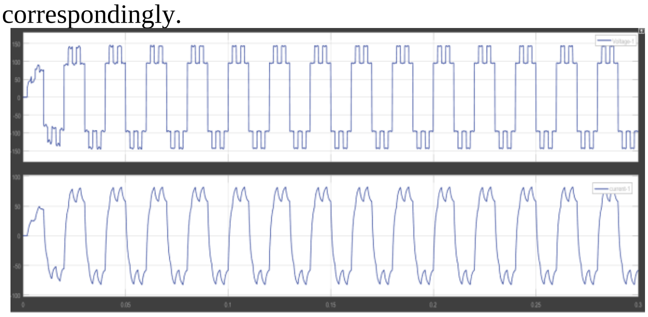

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Fig.9 phase voltage and phase current waveforms without single tuned filter for Five-Phase PWM Inverter drive

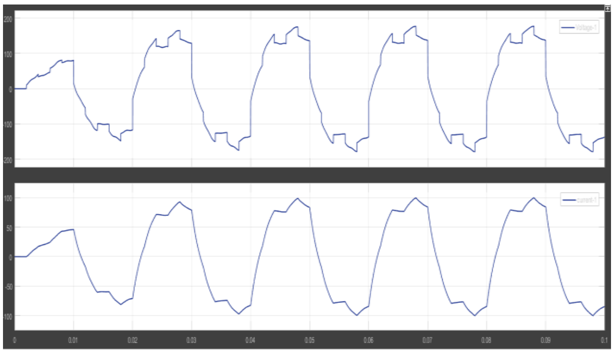

Fig.10 phase voltage and phase current waveforms with single tuned filter for Five-Phase PWM Inverter drive

Table3: Comparison of Total Harmonics Distortion for 50 Hz PWM inverter with and without single tuned filter.

Modes	THD (%)
Without Filter	42.92
With Single Tuned filter	25.82

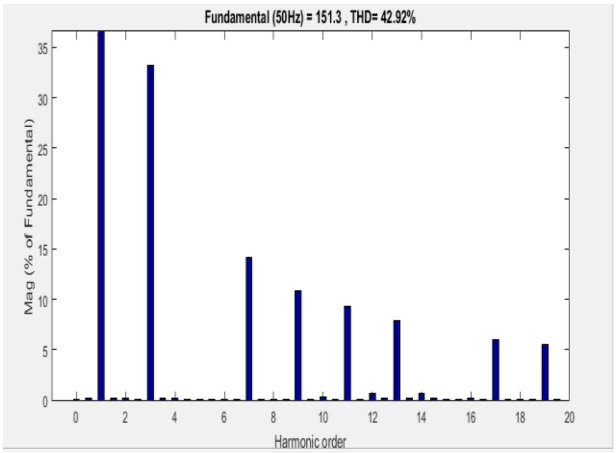

Fig.11. FFT analysis without filter

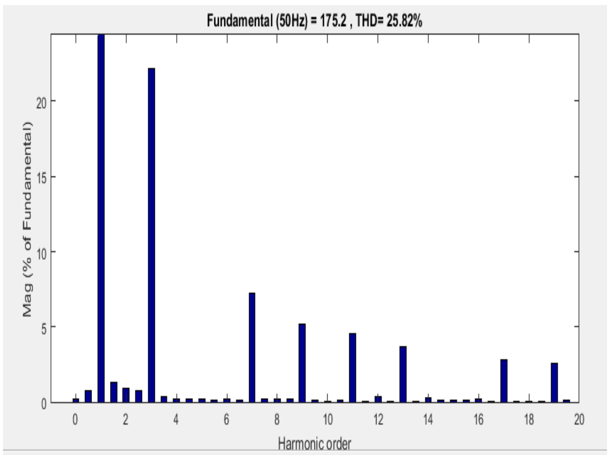

Fig.12. FFT analysis with filter

Different order of Harmonics can be evaluated for Inverter Drive with single tuned filter and without filter in MATLAB.

Table 4: Percentage of different order Harmonics for both conditions (with & without filter)

Order of Harmonics	(%) of harmonics without single tuned filter	(%) of harmonics with single tuned filter
1st	100	100
2nd	0	0
3rd	33.26	22.21
4th	0	0
5th	0	0
6th	0	0
7th	14.23	7.27
8th	0	0
9th	10.87	5.17
10th	0	0
11th	9.33	4.57
12th	0	0
13th	7.92	3.7
14th	0	0
15th	0	0
16th	0	0
17th	5.96	2.84
18th	0	0
19th	5.55	2.54

Table 5: Voltage of different order Harmonics for both conditions (with & without filter)

Order of Harmonics	without single tuned filter (V)	with single tuned filter (V)
1st	151.13	175.2
2nd	0	0
3rd	50.26	38.91
4th	0	0
5th	0	0
6th	0	0
7th	21.50	12.74
8th	0	0
9th	16.43	9.06
10th	0	0
11th	14.10	8
12th	0	0
13th	11.97	6.48
14th	0	0
15th	0	0

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16th	0	0
17th	9.1	4.97
18th	0	0
19th	8.39	4.45

IX. CONCLUSION

From the above analysis various results has been concluded which indicates that a conventional P&O LMS filter method use to track the MPP under different environmental conditions during partial shading and rapid changes in irradiance. The maximum power which is obtained is useful for working of industrial load and also to eliminate the effect of harmonics a suitable single tuned filter is constructed which is being connected at the output terminals of the 5 phase inverter which helps to minimize the amount of total harmonic distortion as well as harmonics. At the end comparison analysis is done in Matlab/Simulink with and without single tuned filter which indicates that total harmonic distortion and harmonics are found to be very less with filter.

REFRECES

1. Gazia Manzoor, Kamalkant Sharma, Satyanand Vishwakarma"PSO-GSA based MPPT Algortihm for Photovoltaic Sytems", International Journal of Recent Technology and Engineering (IJRTE), ISSN:2277-3878, vol.7, issue-6S4, April 2019
2. Mohd H.S Alrashdan,Wael H AL-Sawalmeh, Mohammad Ibrahim ALsharari "Multi-Variables, Single Objective Optimal Power Flow Using Artificial Bee Colony Algorithm", IJAER, ISSN 0973-4562, vol.-14, No. 7, pp. 1507-1515, 2019
3. Arnold F Sagonda, Komla A folly, Ainah P Kenneth," Comparison of Three Techniques for Maximum Power Point Tracking of Solar PV", ISBN:978-1-5090-6020-7/18
4. Z.zandi, A.H.Mazinan"Maximum power point tracking of the solar power plants in shadow mode through artificial neural network",springer,march-7-2019, https://doi.org/10.1007/s40747-019-0096-1
5. J. Ahmed and Z. Salam, "A maximum power point tracking (MPPT) for PV system using cuckoo search with partial shading capability," Appl. Energy, vol. 119, pp. 118–130, Apr. 2014.
6. F. Paz and M. Ordonez, "Zero oscillation and irradiance slope tracking for photovoltaic MPPT," IEEE Trans. Ind. Electron., vol. 61, no. 11, pp. 6138–6147, Nov. 2014.
7. S. K. Kollimalla and M. K. Mishra, "A novel adaptive P&O MPPT algorithm considering sudden changes in the irradiance," IEEE Trans. Energy Convers., vol. 29, no. 3, pp. 602–610, Sep. 2014.
8. Vpiasha Sharma, Harpreet Kaur, Inderpreet Kaur,"Design and Implemetation of Multi Junction PV cell for MPPT to improve the Transformation efficiency " International Journal of Recent Technology and Engineering (IJRTE), ISSN:2277-3878,vol.7, issue-6S4, April 2019
9. Ritik Yadev, Birinderjit singh Kalyan,"Reduction of Low order Harmonic in Multilevel Inveter using hybrid algorithm",IJRECE , vol.6, issue.2, April-June, ISSN:2348-2281.
10. G.Nageswara Rao"Analysis of cascaded H-bridege multilevel inverter for Effectiveness of APF with integration control", (IJRTE), ISSN:2277-3878, Volume-7, Issue-6S2, April 2019
11. Shefali, Harvinder Singh, Sachin Kumar, Inderpreet Kaur," Designing and Imulation of Solar module in the Islanded network of a solar PV microgrid", International Journal of Recent Technology and Engineering (IJRTE), ISSN:2277-3878, Volume-7, Issue-6S4, April 2019
12. Amanpreet singh, Navpreet Kaur, Parminder singh,"Adaptive filtering based MPPT Tracking of solar energy systems" imperial journal of inter disciplinary research, ISSN:2454-1362,vol.3,issue.6,2017
13. Obaidullah Lodin , Inderpreet Kaur, Harpreet Kaur "Predictive- P&O Mppt Algorithm for Fast and Reliable Tracking of Maximum Power Point in Solar Energy Systems", International Journal of Recent Technology and Engineering (IJRTE), ISSN:2277-3878, Volume-7, Issue-6S4, April 2019

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