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***Research paper***

# Improvement of Solar Energy System Under Partial Shading Conditions in Koneru Lakshmaiah Education Foundation

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**Abstract**

This paper consists of grid connected Solar photovoltaic (SPV) system. An output of SPV depends on the irradiation and temperature. Sometimes PV module is shaded due to nearby buildings, passing clouds etc. Power extracted from such partially shaded PV array is reduced. . The PV system at KLEF deemed to be university is considered. Total Harmonic Distortion (THD) and the output powers are computed using Matlab/Simulink using LC filter .These are compared with the actual values measured from the existing system . It is found that percentage of THD is reduced.

***Keywords***: *Matlab/Simulink, Partial shading Photovoltaic cells,*

## 1. Introduction

The Solar, wind and tidal are renewable energy resources which are freely and easily available and limitless and it is friendly to environment. Now a days these resources are also considered for power production .

The most promising alternatives for prevailing energy sources are solar energy source and wind energy source .PV systems are most commonly used because they are clean and availability of source for free of cost. Though, a major task in using a PV source is due to its nonlinear characteristics, which changes with the temperature and solar irradiation. The features become quite complex if the entire PV array does not accept Homogeneous irradiation. In partially shaded conditions result in various values in voltage and power. The presence of maximum peaks in voltages and power shrinks the of the existing Maximum power point .The Maximum Power Point Tracking (MPPT) schemes [1] are used in differencing local and global peaks. If there is no sunlight available, then the grid interface systems use power from central utility when it needs. It supplies surplus generated power back to utility. The power electronic devices are used for the interface of the Pv system with the ac and dc loads.

Even though the installation cost of PV System is very high ,the overall cost can be reduced since the operating cost is less . However the power from solar modules is reduced due to factors such as shading,bird-droppings,hot-spot formation, cell damage and semiconductor material defects.

## 2. Maximum Power Point Tracking

With respect to varying weather conditions like high temperature, irradiance we need to track the maximum output power. The MPPT controller tracks the maximum power point from the PV characteristics. In this system we are using the perturb and observe method .This method is used to track MPP as it is simple and fast in execution .In this method it measures the output voltage and current from the pv panel and calculates the power. The obtained power is compared with the previous iteration power and sends the signal to the inverter to adjust the duty cycle accordingly. Due to varying weather conditions like, temperature, irradiance, the PV system has irregular V-I characteristics and have a unique maximum power point. With respect to changing weather conditions we need to track maximum power output by PV array. In this work, perturb and observe (P&O) algorithm is used to track MPP as it is simple and fast in execution. This algorithm compares previous and present powers and voltages and adjusts the duty cycle accordingly. The flowchart of P&O algorithm is shown in fig.1.

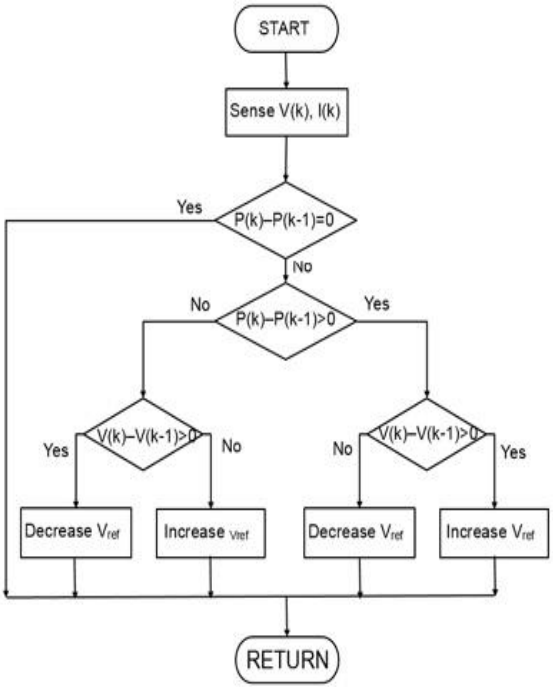



**Fig. 1:** Flowchart of Perturb and Observe method.

## 3. System Description

The existing system is designed with total generation of 75 kVA and . The panels, which are used in PV array, are TS250. The PV arrays having the generation of 30KVA ,30KVA,15 kVA are connected to the main grid .The Electrical parameters of TS250 PV array are given Table-1.

**Table-1:** Electrical Parameters of TS250 PV Module

| Parameter | | Value |
|---|---|---|
| Model | : | TS250 |
| Nominal Output Power (W) | : | 250 |
| Power Tolerance (%) | : | ±2.5 |
| Module Efficiency (η %) | : | 15 |
| Open Circuit (OC) Voltage $V_{OC}$ (V) | : | 38.1 |
| Short Circuit (SC) Current $I_{SC}$ (A) | : | 8.58 |
| Voltage at $P_{MAX}$ $V_{MPP}$ (V) | : | 30.7 |
| Current at $P_{MAX}$ $I_{MPP}$ (A) | : | 8.16 |

A resistive load of 3.5 MVA is connected to the system. The same parameters are used in other arrays also . Each system comprises of a PV array connected to an Inverter which is connected to grid through filter and a circuit breaker. The parameters of overall system is given in Table 2. The Synchronous Reference Frame control technique is used in the inverter to synchronize the PVcell with the grid.

The block diagram of the entire system is shown in Fig2 .

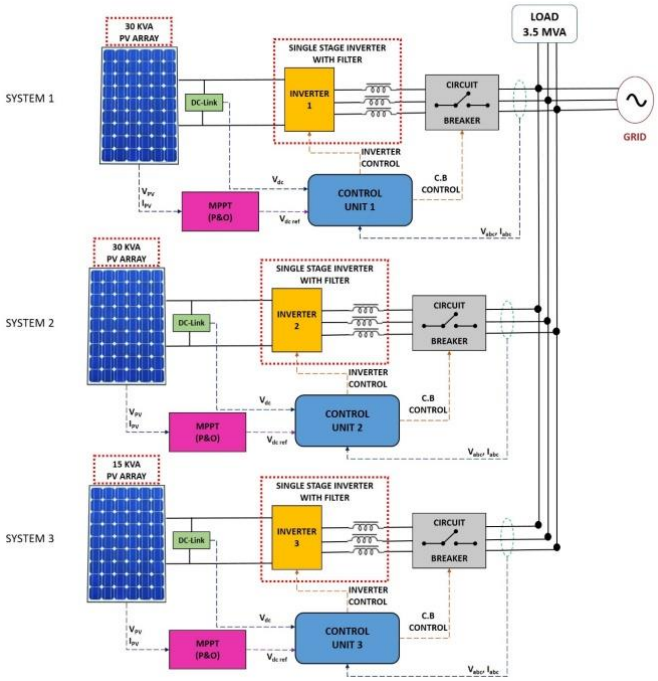



**Fig.2:** Block Diagram Representation of Total System

**Table-2:** Specifications of overall SetUp

| Specifications | Value | | |
|---|---|---|---|
| | System 1 | System 2 | System 3 |
| No. of PV modules | 125 | 125 | 60 |
| Power from PV Array (KVA) | 30 | 30 | 15 |
| Technique used by MPPT | P&O | P&O | P&O |
| DC Link Voltage (V) | 760 | 760 | 760 |
| Inverter Rating (KVA) | 30 | 30 | 15 |
| Inverter Type | 3 Level IGBT Bridge | 3 Level IGBT Bridge | 3 Level IGBT Bridge |
| Inverter Control | SRF Control | SRF Control | SRF Control |
| Output Voltage (V) | 415 | 415 | 415 |

## 4. Control Strategy

The purpose of the of the control strategy is to sustain the constant dc voltage of the DC grid and maintain the load demand power under various partial shading conditions .The PV module is integrated with the grid by control strategy of Synchronous reference frame of control .The schematic diagram for the VSC is illustrated in Fig.3. To satisfy the synchronizing conditions, the inverter control employs Synchronous Reference Frame control to synchronize inverter with grid.

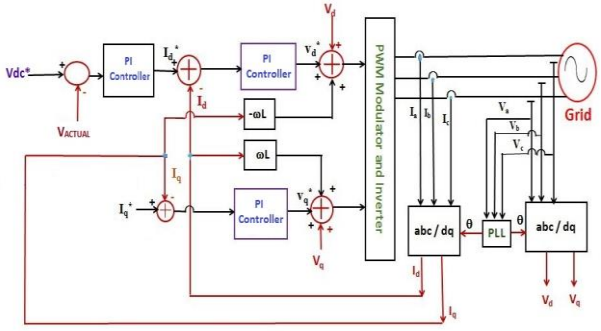



**Fig.3:** Schematic diagram of Synchronous frame of reference control

The park's transformation is used for converting 3-phase system into dqo system. Due to this transformation the control variables are converted into dc. This facilitates controlling and filtering easier. A schematic diagram of the dq control is presented in Fig.3 Hence the DC link voltage is controlled to get the necessary

dc output power. The PI controller is used to reduce the difference of the voltages from the grid and pv system..

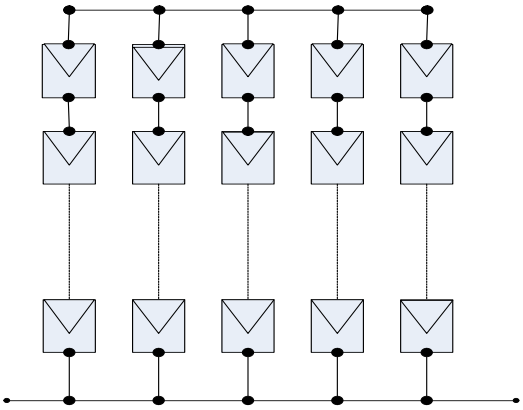
$$G_{pi}^{dq}(S) = \begin{bmatrix} \frac{k_p + k_I}{s} & 0 \\ 0 & \frac{k_p + k_I}{s} \end{bmatrix}$$

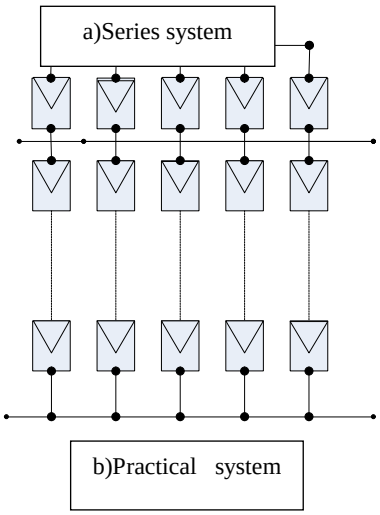
So far the previous researchers have done series connection of the pv array parallel connection and some of them also did series parallel connection also . In the series method major loss occurs in the partial shading condition . When the photo voltaic cells connected either series or parallel the mismatch losses will increase efficiency and performance will be reduced [5]. To improve its performance series parallel connection is used in this paper under partial shading condition.

This method is applied for existing practical system in KLEF (deemed to be university).

The details of the system are given below

Here we have considered the KLEF system with 75kVA generation having 120 TS250 solar panels which are connected in series and parallel connection to the grid for simulation purpose with the transformer as shown in fig4c . The solar cells are actually connected in series and parallel connection in the KLEF as shown in fig 4b. The output power readings along with the percentage of the harmonic content are given in the table 3, by simulation and actual measurements [15, 16].





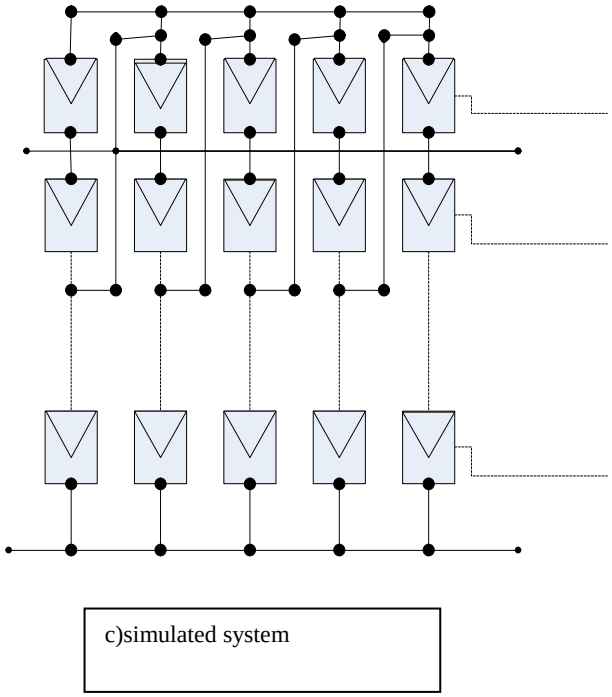




**Fig 4 .**represents the various connections ofsolar cells

**Table.3:** Comparison of Harmonics and Power with simulated method(series parallel connection of pv cells ) and previous method(series connection of Pv cells).

| Time | Irradiance ($W/m^2$) | Temperature ($^oc$) | Power (kWh) | | | Harmonics | | |
|---|---|---|---|---|---|---|---|---|
| | | | Series connection of pv cells | Series & Parallel connection of pv cells | Series & Parallel connection of pv cells (simulated system ) | Series connection of Pv cells | Series & Parallel connection of Pv cells | Series & Parallel connection of pv cells (simulated ) |
| 9:00 AM | 207 | 34 | 5.492 | 15.525 | 18.25 | 10.35 | 8.75 | 3.7 |
| 10:00 AM | 424 | 43 | 15.63 | 31.8 | 35.7 | 6.35 | 4.3 | 1.5 |
| 11:00 AM | 640 | 48 | 30.04 | 48 | 52.4 | 5.05 | 1.99 | 0.96 |
| 12:00 PM | 725 | 52 | 35.44 | 54 | 58.52 | 4.29 | 1.17 | 0.88 |
| 1:00 PM | 859 | 55 | 42.54 | 64.425 | 68.1 | 4.05 | 1.02 | 0.7 |
| 2:00 PM | 838 | 54 | 41.5 | 62.82 | 66.05 | 3.85 | 1.32 | 0.75 |
| 3:00 PM | 746 | 51 | 32.45 | 55.95 | 59.12 | 3.65 | 2.43 | 0.8 |
| 4:00 PM | 552 | 42 | | | | | 2.52 | 1.08 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 24.8 | 41.4 | 46.95 | 3.05 | | |
| 5:00 PM | 359 | 38 | 10.61 | 26.925 | 36.2 | 3.02 | 2.89 | 2.5 |

It is observed from the above table that the harmonic content is 1.4% by simulation method whereas its is 2.94% in real time measurement for KLEF sytem. The energy generated is also calculated using simulation method. It is 435KWh per day. But the actual measured value in real time from the system is 400.25KWh per day .Hence it is concluded that the simulated method is giving the better results.

## 5. Cost Analysis

The cost analysis is done for the system considered as follows.

Difference of the measured and calculated Energy in a day (kWh )= 35.815 kWh.

Cost of 1 unit of energy is = Rs 6.41/kWh.

The amount of money due to excess power generation in the existing system per 15year = 6.41*35.81*365*15= Rs12,29,355. (1)

The cost of 75kVA transformer for is Rs 1,92,840

The cost of DC-DC converter is Rs 25,950

The Difference on the capital cost = Rs1,66,890. (2)

The amount of interest on difference in capital cost for 15 years

166890*15*10/100 =Rs2,50,335 (3)

The excess of operating cost due to presence of transformer is Rs 65,000/Year (Taken from internet)

For 15 years the operating cost is 65000*15=Rs9,75,000 (4)

The total saving in the proposed method in 15years is

(1)+(2)+(3)+(4)=12,29,335+166890+250355+9,75,000

Approximately the profit by adopting the proposed method is RS 26,25,000 in the span of 15 years .

## 6. Results

The solar power generated by KLEF system is estimated 435KWh per day using simulated method .where as by actual measurement it is 400.25KWh perday. The harmonic distortion observed in real time system is 2.94% whereas it is 1.4% by calculation using simulated method.

## 7. Conclusion:

In this paper the KLEF renewable power generation system is considered .The simulated method (as shown in fig4c) is used for calculation of power generation for the same system. The cost of generation with the existing type of connection (as shown in fig4b) is compared with that of simulated method . It is found that there is a significant decrease in Total harmonic distortion by 1.5% and the energy production is increased by 10%. The saving is Rs 26,25,000 for 15years .Thus solar power system in KLEF will be improved if series parallel connected for PV cells is adopted.

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