ROBUST PARTIAL FEEDBACK LINEARIZING STABILIZATION

M. Mahesh Babu[1], S. Chandrakiran[2]

[1]*M.Tech student, EEE, Dr.K.V.Subbareddy college of Institute &Technology, Andhra Pradesh, India*

[2]*Assistant professor, ,EEE, Dr.K.V.Subbareddy college of Institute &Technology, Andhra Pradesh, India*

Abstract- **This project presents a stabilization scheme for a three-phase grid-connected photovoltaic (PV) system to control the current injected into the grid and dc-link voltage to extract maximum power from photovoltaic (PV) units. The scheme is achieved mainly based on the design of a controller using a partial feedback linearizing approach of feedback linearization where the stabilization of the scheme is ensured by considering uncertainties within the PV system mode. The performance of the stability enhancement is evaluated on a three-phase grid-connected PV system in terms of delivering maximum power under changes in atmospheric conditions. In the grid connected PV system the control objectives are met by a strategy using a pulse width modulation (PWM) scheme based on two cascaded control loops. The two cascaded control loops consist of an outer voltage control loop to settle the PV array at the Maximum Power Point (MPP) and an inner current control loop to establish the duty ratio for the generation of a sinusoidal output current which is in phase with the grid voltage.**

Index Terms- **Grid-connected photovoltaic (PV) system, matching conditions, nonlinear controller, partial feedback linearizing scheme, structured uncertainty.**

I. INTRODUCTION

The demand for renewable energy has increased significantly over the years because of shortage of fossil fuels and greenhouse effect. Among various types of renewable energy sources, solar energy has become very popular and demanding due to advancement in power electronics techniques. Photovoltaic (PV) sources are used today in many applications as they have the advantages of being maintenance and pollution free. Solar-electric-energy demand has grown consistently by 20%–25% per annum over the past 20 years, which is mainly due to the decreasing costs and prices. This decline has been driven by the factors of an increasing efficiency of solar cells, manufacturing technology improvements and economies of scale. PV inverter, which is the heart of a PV system, is used to convert dc power obtained from PV modules into ac power to be fed into the grid. Grid-connected PV systems are nonlinear systems where most of the nonlinearities occur due to the intermittency of sunlight and the switching functions of converters and inverters. To ensure the operation of a grid-connected PV system over a wide range of operating points, the design and implementation of a nonlinear controller is important [1].

Linear controllers such as proportional-integral (PI) [2], hysteresis controller [3], and model predictive controllers [4] provide satisfactory operation over a fixed set of operating points as the system is linearized at an equilibrium point. The PV source exhibits a strongly nonlinear electrical behavior due to the variation of solar irradiance and nonlinear switching functions of inverters. As linear controllers for nonlinear PV systems affects all the variables in the system and the electrical characteristics of the PV source are time varying, the system is not linearizable around a unique operating point or trajectory to achieve a good performance over a wide variation in atmospheric conditions. A non-linear controller namely robust controller for a grid-connected PV system is proposed along with a MPPT technique to provide robust tracking performances. Because of the high initial investment, variations in solar irradiation, and reduced life-time of PV systems, as compared with the traditional energy sources, it is essential to extract maximum power from PV systems. Maximum power point tracking (MPPT) techniques are widely used to extract maximum power from the PV system that is delivered to the grid through the inverter [5].

A. Recent improvements on MPPT

can be seen in [5] and [6]. Interconnections among PV modules within a shaded PV field can affect the extraction of maximum power [7]. A study of all possible shading scenarios and interconnection schemes for a given PV field, to maximize the output power of PV array, is proposed in [7]. Inverters interfacing PV modules with the grid perform two major tasks—one is to ensure that PV modules are operated at maximum power point (MPP), and the other is to inject a sinusoidal current into the grid. In order to perform these tasks effectively, efficient stabilization or control schemes are essential.

II. PHOTOVOLTAIC SYSTEM MODEL.

The schematic diagram of a three-phase grid-connected PV system, which is the main focus of this paper, is shown in Fig. 1. The considered PV system consists of a PV array, a dc-link capacitor C, a three-phase inverter, a filter inductor L, and grid voltages e_a, e_b, e_c. In this paper, the main aim is to control the voltage v_{dc} (which is also the output voltage of PV array v_{pv}) across the capacitor C and to make the input current in phase with grid voltage for unity power factor by means of appropriate control signals through the switches of the inverter.

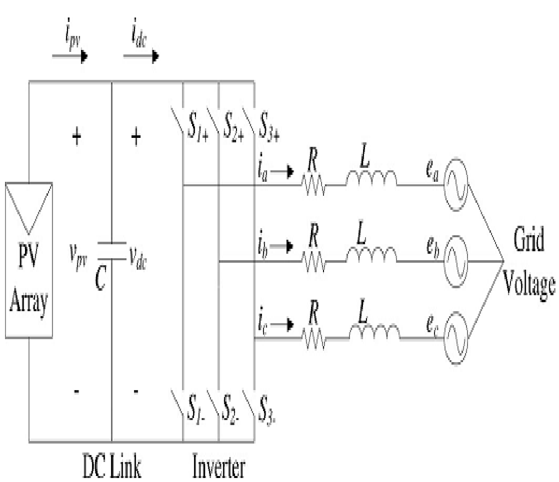

Fig. 1. Three-phase grid-connected PV system.

A. Photovoltaic system designing

The PV cell is the p-n junction diode which converts the light energy into electricity. Figure 2 shows the solar cell consist of an light generated current source, diode(D), shunt resistance RSH and the series resistance RS.

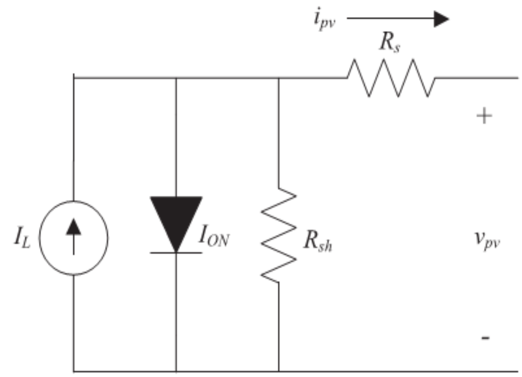

Fig. 2. Equivalent circuit diagram of the PV cell.

$$I_0 = I_{rr}\left[\left(\frac{T}{T_r}\right)^3\right]\exp\left(\frac{qE_{gv}}{BK}\left(\frac{1}{T_r}-\frac{1}{T}\right)\right) \qquad (1)$$

Where is the dark saturation current, I_D is the saturation current at T_r, q is the charge of an electron, A and B is the diode quality (Ideality) factor whose value is between 1to 5, k is the Boltzmann constant, T is the absolute temperature in Kelvin, and Egv is the band gap energy of the semiconductor used in the cell, The light generated current that is depend on the solar intensity that is given as

$$I_{ph} = \left[I_{scr} + K_i[T-298]\right]\lambda/_{1000} \qquad (2)$$

The output voltage of the PV cell is given by

$$V_{pv} = \left[\frac{N_s ATK}{q}\right]\ln\left[\frac{N_p I_{ph} - I_{pv} + N_p I_0}{I_0}\right] - I_{pv}R_s \qquad (3)$$

Where and are the number of cell in series and the number of panel in the parallel and if the the value of the and can be varied, then the PV voltage and current can be varied. and is the series and shunt resistance of the PV cell. RS is the resistance offered by the contacts andthe bulk semiconductor material of the solar cell. The shunt resistance RSH is related to the non –ideal nature of the p–n junction andthe presence of impurities near the edges of the cell that provide a short-circuit patharound the junction. The output current of the PV cell can be written as,

$$I_{pv} = N_p I_{ph} - N_p I_0\left[\exp\left[\frac{q(V_{pv}+I_{pv}R_s)}{N_s ATK}\right] - 1\right] \qquad (4)$$

Fig. 3 shows an electrical equivalent circuit diagram of a PV array, where Ns is the number of cells in series, and Np is the number of modules in parallel.

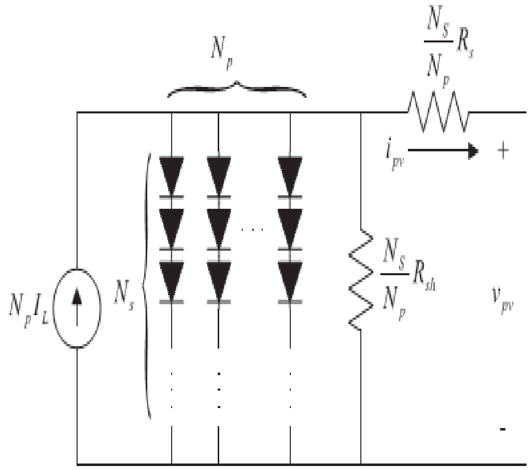

Fig. 3. Equivalent circuit diagram of the PV array.

III. PROPOSED DESIGN OF ROBUST CONTROLLER

Robust control is a branch of control theory which approach to controller design explicitly deals with uncertainty. Robust control methods are designed to function properly provided that uncertain parameters or disturbances are found within some set. Robust methods aim to achieve robust performance and/or stability in the presence of bounded modeling errors.
Robust controller design explicitly deals with disturbances or uncertainties [9]. Robustness concerns how a system reacts to erroneous or failed inputs or stressful environmental conditions. Robust control systems often incorporate advanced topologies which include multiple feedback loops and feed forward paths. The representation of the robust controller including the uncertainties is shown in Fig.4

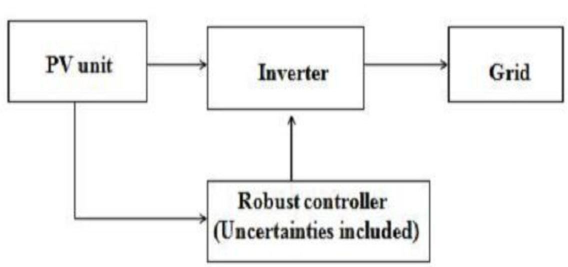

Fig. 4: Robust controller

If the uncertainties are considered in the PV system model, the partial feedback linearization stabilization scheme cannot stabilize the system. But with the robust partial feedback linearization stabilization scheme by considering uncertainties in the system, the operation of the system is maintained at unity power factor since both the grid voltage and grid current are in phase with each other. Two steps are involved in designing the robust control law [10].They are

Step 1: Partial feedback linearization stabilization scheme

Non-linear grid connected PV system can be converted to partially linearized PV system by considering this step. The two linear control inputs which are obtained from two PI controllers are given as follows:

$$V_1 = -wI_d - \frac{R}{L}I_q - \frac{E_q}{L} + \frac{v_{pv}}{L}K_q \dots \dots .(\,)$$

$$V_2 = \frac{1}{C}I_{pv} - \frac{1}{C}I_d k_d - \frac{1}{C}I_q K_q \dots \dots . \dots .(\,)$$

$$K_d = \frac{L}{v_{pv}}\left(v_1 + wI_d + \frac{R}{L}I_q + \frac{E_q}{L}\right) \dots (\,)$$

$$K_q = -\frac{C}{I_q}[v_2 + \frac{i_{pv}}{C} - \frac{LI_d}{Cv_{pv}}(v_1 + wI_d + \frac{R}{L}I_q + \frac{E_q}{L}]$$

The controller performance is evaluated based on the implementation block diagram which
is shown in Fig.5

K_d = 0.85 L/V_{pv} (v_1 + 1.36ωI_d + 1.042R/ LI_q + 1.23Eq/L……………

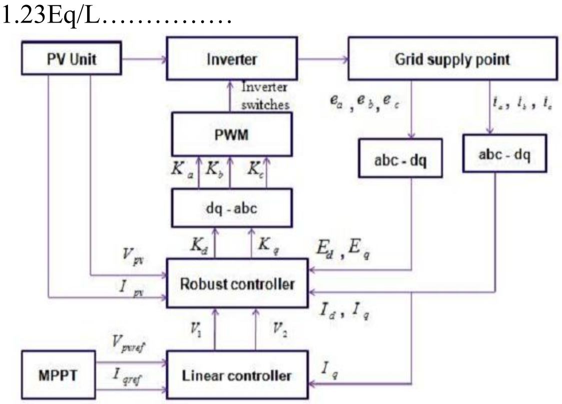

Fig.5: Implementation block diagram

Some of the uncertain parameters are not exactly known or difficult to estimate. Therefore, to evaluate the performance of the designed robust control scheme, it is essential to consider these uncertainties in the robust controller. A PWM technique is used to make the input signals suitable for the switches.

IV. SIMULATION RESULTS AND DISCUSSIONS

An extensive simulation study has been carried out for robust stabilization scheme in order to verify the proposed control strategy.

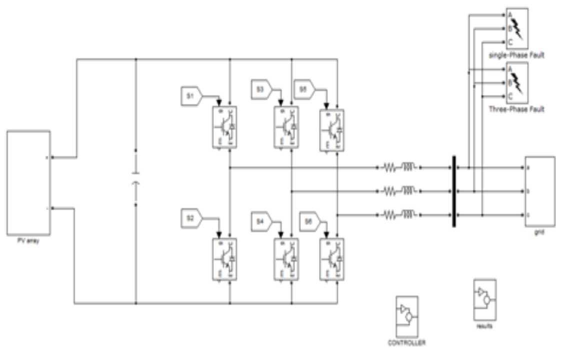

Fig.6

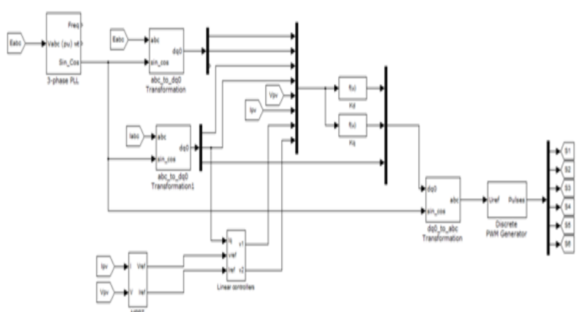

Fig.7

The system under consideration is simulated using the Sim Power System tool box of MATLAB/Simulink. The proposed system overall block diagram is shown in Fig. 6 and the output voltage and current of the grid are shown in Fig.7.

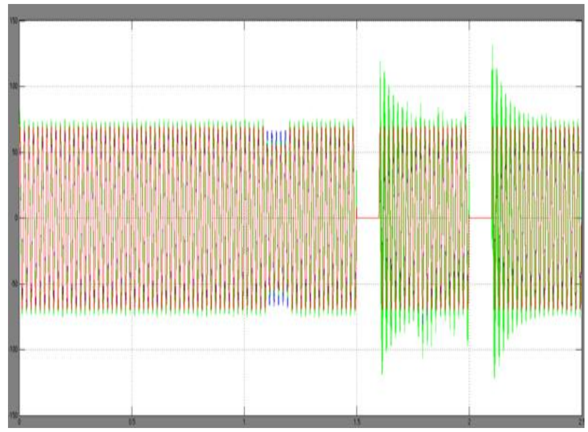

Fig.8

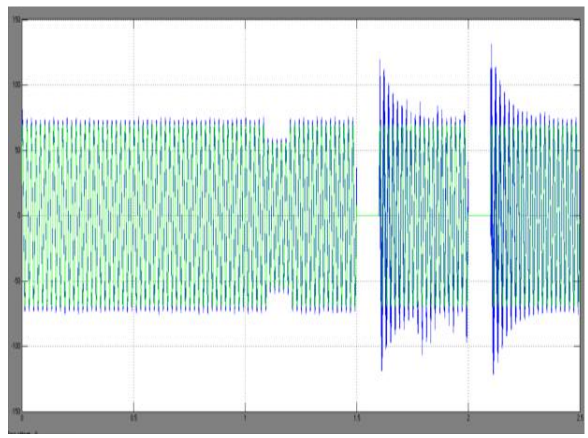

Fig.9

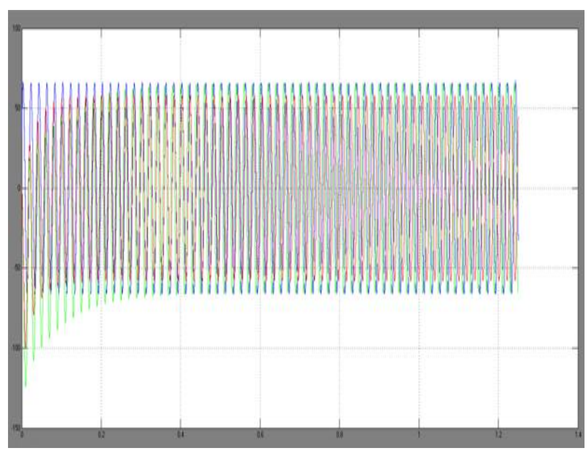

Fig.10

V. CONCLUSION

In this project, stability enhancement of a three-phase grid-connected PV system is done by modeling the uncertainties to ensure the operation of the system at unity power factor., The partial feedback linearization approach is used, and with the designed scheme, only the upper bounds of the PV systems parameters and states need to be known rather than network parameters, system operating points. The resulting scheme enhances the overall stability of a three-phase grid connected PV system, considering admissible network uncertainties. Thus, this stabilization scheme has good stabilization against the PV system parameter variations, irrespective of the network parameters and configuration

REFERENCES

[1] M.A. Mahmud, H.R. Pota, M.J. Hossain and N.K. Roy, “Robust partial feedback linearizing stabilization scheme for three-phase grid-connected photovoltaic systems,” IEEE J. Photovoltaics, vol. 4, no. 1,pp. 423– 431, Jan. 2014.

[2] J. Selvaraj and N. A. Rahim, “Multilevel inverter for grid-connected PV system employing digital PI controller,” IEEE Trans. Ind. Electron., vol. 56, no. 1, pp. 149–158, Jan. 2009.

[3] N. A. Rahim, J. Selvaraj, and C. C. Krismadinata, “Hysteresis current control and sensorless MPPT for grid- connected photovoltaic systems,” in Proc. IEEE Int. Symp. Ind. Electron. 2007, pp. 572–577.

[4] A.Kotsopoulos, J. L.Duarte, andM. A. M.Hendrix, “Apredictive control scheme for DC voltage and AC current in grid-connected Photovoltaic inverters with minimum DC link capacitance,” in Proc. IEEE Ind. 27th Annu. Conf. Electron. Soc., 2001, pp. 1994–1999.

[5] T. Esram and P. L. Chapman, “Comparison of photovoltaic array maximum power point tracking techniques,” *IEEE Trans. Energy Convers.*, vol. 22, no. 2, p. 439–449,Jun. 2007.

[6] E. Koutroulis and F. Blaabjerg, “A new technique for tracking the global maximum power point of PV arrays operating under partial-shading conditions,” IEEE J. Photovoltaics, vol. 2, no. 2, pp. 184–190, Apr. 2012.

[7] L. F. L. Villa, D. Picault, B. Raison, S. Bacha, and A. Labonne, “Maximizing the power output of partially shaded photovoltaic plants through optimization of the interconnections among its modules,” IEEE J. Photovoltaics, vol. 2, no. 2, pp. 154–163, Apr. 2012.

BIODATA

Author

M. Mahesh Babu presently pursuing his M.Tech in Electrical Power Systems from Dr.K.V.Subbareddy College of Institute &Technology, Andhra Pradesh, India.

Co-Author

S. Chandrakiran received M.Tech. Presently working as Assistant Professor in Dr.K.V.Subbareddy College of Institute & Technology, Andhra Pradesh, India.