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# Modelling and analysis of robust Nonlinear controller of Three phase Grid connected system under structured uncertainties

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## ABSTRACT:

***This paper presents a robust nonlinear controller design for a three-phase grid-connected photovoltaic (PV) system to control the current injected into the grid and the dc-link voltage for extracting maximum power from PV units. The controller is designed based on the partial feedback linearization approach, and the robustness of the proposed control scheme is ensured by considering structured uncertainties within the PV system model. An approach for modeling the uncertainties through the satisfaction of matching conditions is provided. The superiority of the proposed robust controller is demonstrated on a test system through simulation results under different system contingencies along with changes in atmospheric conditions. From the simulation results, it is evident that the robust controller provides excellent performance under various operating conditions.***

*Index Terms*—***Grid-connected PV system, matching conditions, partial feedback linearization, robust nonlinear controller, structured uncertainty***.

## INTRODUCTION:

In Response to global concerns regarding the generation and delivery of electrical power, photovoltaic (PV) technologies are gaining popularity as a way of maintaining and improving living standards without harming the environment. To extract maximum power from the PV system a robust controller is required to ensure maximum power-point tracking (MPPT) and deliver it to the grid through the use of an inverter . Robustness is essential since the power output of PV units varies with changes in atmospheric conditions. Thus, the controller must be robust enough to provide a tighter switching scheme for the inverter to transfer maximum power into the grid over a wide range of operating conditions with a short transient period. In a grid-connected PV system, control objectives are met by 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 track the maximum power point (MPP) and an inner current control loop to control the duty ratio for the generation of a sinusoidal output current which needs to be in phase with the grid voltage for unity power factor operation [7]. The current loop is also responsible for maintaining power quality (PQ) and for current protection that has harmonic compensation. Linear controllers are widely used to operate PV systems at MPP however, most of these controllers do not account for the uncertainties in the PV system. Over the past few decades, one of the most important contributions in the field of control theory and applications has been the development of robust linear controllers for linear systems in the presence of uncertainties through the control scheme which is often obtained from linear matrix inequality (LMI) methods. A feed forward approach is proposed in to control the current and dc-link voltage, and the robustness is assessed through modal analysis. A robus fuzzy-controlled PV inverter is presented in [17] for the stabilization of a grid-connected PV system where the robustness is achieved by using the Taguchi tuning algorithm. A minimax linear quadratic Gaussian (LQG) technique is proposed in to design a robust controller for the integration of PV generation into the

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grid where the higher-order terms during the linearization are considered as modeling uncertainties. The controller design methods as presented[13] and are based on linearizedmodels of nonlinear PV systems. In practice, PV sources are time varying, and the system is not linearizable around a unique operating point or a trajectory to achieve the desired performance over a wide range of changes in atmospheric conditions.

## Existing System:

A three-phase grid-connected PV system is shown in Fig. 1 where the PV array consists of a number of PV cells in a series and parallel combination to achieve the desired output voltage. The detailed modeling of a PV array and cell is given in [25].

The output voltage of the PV array is a dc voltage and, thus, the output dc power is stored in the dc-link capacitor . The output current of the PV array is and that of the dc-link capacitor is . The dc output power of the PV array is converted into ac power through the inverter. The inverter, shown in Fig. 1, is an

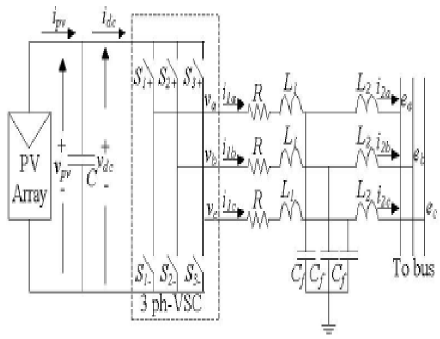


Fig. 1. There-phase grid-connected PV system with an output $LCL$ filter.

## Proposed System:

Since the three-phase grid-connected PV system, as represented by the group of , has two control inputs ( and and the controller needs to be designed with two control objectives and , the mathematical model can be represented by the following form of a nonlinear multi-input multioutput (MIMO) system The design of a partial feedback linearizing controller depends on the feedback lineariz ability of the system, and this feedback linearizability is defined by the relative degree of the system . The relative degree of the system, in turn, depends on the output functions of the system. The nonlinear model of a three-phase grid-connected PV system as shown by (9) can be linearized using feedback linearization when some conditions are satisfied. Consider the following nonlinear coordinate transformation for the aforementioned three-phase grid-connected PV system:

## UNCERTAINTY MODELING

As mentioned earlier, the output power of the PV system depends on the intensity of the solar irradiation which is uncertain because of unpredictable changes in weather conditions. These changes may be modeled as uncertainties in current out of the solar panels which, in turn, causes uncertainties in the current (in the -frame, , and ) injected into the grid. Since the uncertainty in the output power of inverters is related to the frequency of the grid, the proposed scheme has the capability of accounting for the uncertainty in the grid frequency. In addition, the parameters used in the PV model are, in most cases, either time varying or not exactly known and, therefore, parametric uncertainties exist too. Thus, it is essential to represent these uncertainties in PV system models.

## ROBUST CONTROLLER DESIGN

The following steps are followed to design the robust controller for a three-phase grid-connected PV system as shown in The main difference between the designed robust control law (32) and the control law as presented in is the inclusion of uncertainties within the PV system model. Here, the linear control inputs and can be obtained in a similar way as discussed in The performance of the designed robust stabilization scheme is evaluated and compared in the following section to that without any uncertainty as presented in along with the direction of practical implementation.

## Controller Performance Evaluation

To evaluate the performance of the three-phase grid-connected PV system with the designed robust

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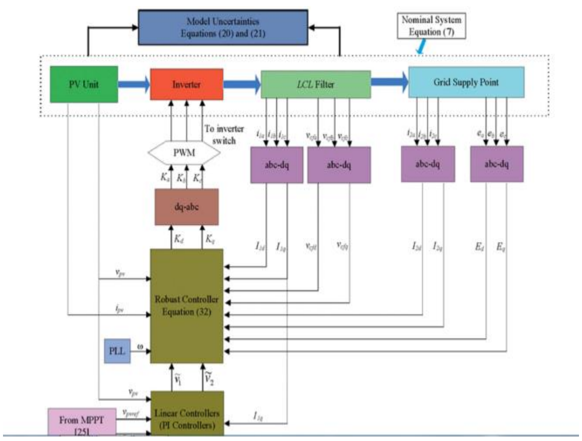
controller, a PV array with 20 strings each characterized by a rated current of 2.8735 A is used. Each string is subdivided into 20 modules characterized by a rated voltage of 43.5 A and connected in series. The total output voltage of the PV array is 870 V, the output current is 57.47 A, and the total output power is 50 kW. The value of the dc-link capacitor is 400 F, the line resistance is 0.1 , and inductance is 10 mH. The grid voltage is 660 V and the frequency is 50 Hz. The switching frequency of the inverter is considered as 10 kHz.



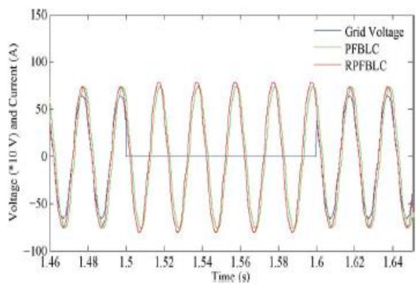




Fig. 7. Controller performance during the single-line-to-ground fault.

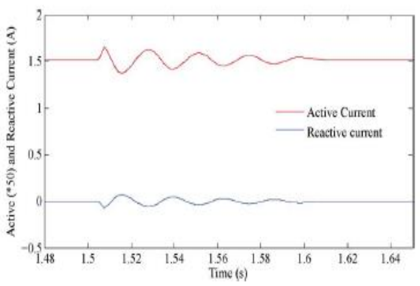



Fig. 8. Positive-sequence active ($I_q$) and reactive ($I_d$) current during the single-line-to-ground fault.

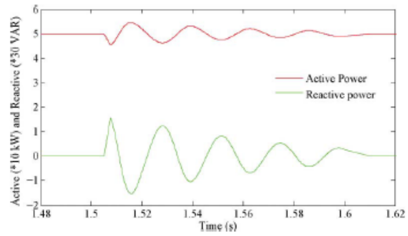



Fig. 9. Negative-sequence active ($P$) and reactive ($Q$) power during the single-line-to-ground fault.

## CONCLUSION

A robust controller is designed by modeling the uncertainties of a three-phase grid-connected PV system in a structured way based on the satisfaction of matching conditions to ensure the operation of the system at unity power factor. The partial feedback linearizing scheme is employed to obtain the robust control law and with the designed control scheme, only the upper bounds of the PV systems' parameters and states need to be known rather than network parameters, system operating points, or natures of the faults. The resulting robust controller enhances the overall stability of a three-phase grid-connected PV system considering admissible network uncertainties. Thus, this controller has good robustness against the changes in parameters and variations in atmospheric conditions irrespective of the network parameters and configuration. Future work will include the implementation of the proposed control scheme on a practical system.

## REFERENCES

[1] S. Jain and V. Agarwal, "A single-stage grid connected inverter topology for solar PV systems with maximum power point tracking," *IEEE Trans. Power Electron.*, vol. 22, no. 5, pp. 1928–1940, Sep. 2007.

[2] U. Zimmermann and M. Edoff, "A maximum power point tracker for long-term logging of PV module performance," *IEEE J. Photovolt.*, vol. 2, no. 1, pp. 47–55, Jan. 2012.

[3] E. Koutroulis and F. Blaabjerg, "A new technique for tracking the global maximum power point of PV arrays operating under partialshading conditions,"

*IEEE J. Photovolt.*, vol. 2, no. 2, pp. 184–190, Apr. 2012.

[4] S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, "A review of single-phase grid-connected inverters for photovoltaic modules," *IEEE Trans. Ind. Appl.*, vol. 41, no. 5, pp. 1292–1306, Sep./Oct. 2005.

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

[6] I. Houssamo, F. Locment, and M. Sechilariu, "Maximum power point tracking for photovoltaic power system: Development and experimental comparison of two algorithms," *Renew. Energy*, vol. 35, no. 10, pp. 2381–2387, Oct. 2010.

[7] F. Blaabjerg,R. Teodorescu,M.Liserre, and A. V. Timbus, "Overview of control and grid synchronization for distributed power generation systems," *IEEE Trans. Ind. Electron.*, vol. 53, no. 5, pp. 1398–1409, Oct. 2006.

[8] A. Kotsopoulos, J. L. Darte, and M. A. M. Hendrix, "Predictive DC voltage control of single-phase pv inverters with small dc link capacitance," in *Proc. IEEE Int. Symp. Ind. Electron.*, Jun. 2003, pp. 793–797.

[9] C.Meza, J. J.Negroni,D. Biel, and F. Guinjoan, "Energy-balance modeling and discrete control for single-phase grid-connected PV central inverters," *IEEE Trans. Ind. Electron.*, vol. 55, no. 7, pp. 2734–2743, Jul. 2008.

[10] R. Kadri, J. P. Gaubert, and G. Champenois, "An improved maximum power point tracking for photovoltaic grid-connected inverter based on voltage-oriented control," *IEEE Trans. Ind. Electron.*, vol. 58, no. 1, pp. 66–75, Jan. 2011.

[11] 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.

[12] 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.

[13] A. Kotsopoulos, J. L. Duarte, and M. A. M. Hendrix, "A predictive control scheme for DC voltage and AC current in grid-connected photovoltaic inverters with minimum DC link capacitance," in *Proc. 27$^{th}$ Annu Conf. IEEE Ind. Electron. Soc.*, 2001, pp. 1994–1999.

[14] M. Chilali and P. Gahinet, " -design with pole placement constraints: An LMI approach," *IEEE Trans. Autom. Control*, vol. 41, no. 3, pp. 358–367, Mar. 1996.

[15] K. Zhou and J. C. Doyle, *Essentials of Robust Control*. Upper Saddle River, NJ, USA: Prentice-Hall, 1998.

[16] A. Yazdani and P. P. Dash, "A control methodology and characterization of dynamics for a photovoltaic (PV) system interfaced with a distribution network," *IEEE Trans. Power Del.*, vol. 24, no. 3, pp. 1538–1551, Jul. 2009.

[17] Y.-K. Chen, C.-H. Yang, and Y.-C.Wu, "Robust fuzzy controlled photovoltaic power inverter with Taguchi method," *IEEE Trans. Aerosp. Electron. Syst.*, vol. 38, no. 3, pp. 940–954, Jul. 2009.

[18] M. J. Hossain, T. K. Saha, N. Mithulananthan, and H. R. Pota, "Robust control strategy for PV systemintegration in distribution systems," *Appl. Energy*, vol. 99, pp. 355–362, Nov. 2012.

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