LVRT Capability Enhancement of Grid Connected Photo Voltaic Power Plants with Adaptive Control Strategy

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Abstract— **This paper presents a novel application of adaptive control strategy for low voltage ride through capability enhancement of grid connected PV power plants. Through DC-DC boost converter the PV arrays are connected to the point of common coupling (PCC), a DC-link capacitor, a grid side inverter, and a three-phase step up transformer. The DC-DC converter is used for a MPPT operation based on the fractional open circuit voltage method. The grid-side inverter is utilized to control the DC-link voltage and terminal voltage at the PCC through a vector control scheme. The adaptive proportional-integral (PI) controller is used to control the power electronic circuits due to its very fast convergence. With the proposed adaptive-controlled PV power plants, the LVRT capability of such system can be improved. The adaptive control strategy is extensively verified by the simulation results, which are carried out using MATLAB/SIMULINK software.**

Keywords— ***Low voltage ride through (LVRT), Photovoltaic (PV) power systems, Adaptive control, Power system dynamic stability, Power system control.***

I. INTRODUCTION

Nowadays Photovoltaic (PV) system will be one of the most promising renewable energy systems. The costs of the installed PV systems are continuously decreasing worldwide because of falling component average selling prices [1]. Based on the statistics of the PV power plants 2014 industry guide report, the global PV system installations reached 136.7 GW at the end of 2013 and the cumulative market growth reaches 36% [1]. Large integration with the electric grid leads many problems arise and need to solve like low voltage ride through (LVRT) capability enhancement of such systems. With the high level of penetration of the PV power plants in the electric grids, maintaining the grid stability and reliability represents a greater challenge to the network operators [2]. Recently, the utilities have released medium voltage grid codes to the PV systems that impose on these systems to contribute to and have a role in the grid support during grid faults [3].

Several methods have been used to study, analyze, and improve the LVRT capability of the PV systems. In the LVRT capability of single phase grid-connected PV systems was presented using an extensive control method, which depends on controlling both the real and reactive powers out of the PV system [4]. In the impact of dynamic performance of the PV systems on short term voltage stability was introduced [5-6]. A cascaded proportional- integral (PI) control scheme was proposed to control the grid-side inverter. Moreover, many studies have utilized the PI controller for LVRT improvement of grid-connected PV systems [7-9]. However, in all these previous reported studies, the design of the PI controller is based on the trial and error method which depends on the designer experience. Despite robustness of the PI controller and its usage in different industrial applications, it suffers from the sensitivity to parameters variation and nonlinearity of dynamic systems. Recently, different optimization techniques were implemented to solve this problem. Although these optimization methods are very effective to deal with such nonlinear systems, they require complex computational procedures, long times, and significant efforts. Adaptive filtering algorithms have been used to solve several engineering problems in different applications such as signal processing, electronics engineering, audio, speech, and language applications. Recently, these algorithms were explored in electric power systems, since affine projection algorithm was utilized to adapt the PI controller parameters in a wind energy conversion system. In these algorithms, a compromise should be taken into consideration between the algorithm complexity and the convergence speed [10].

II. GRID CONNECTED PV POWER PLANT SYSTEM MODELLING

The PV arrays are connected to bus through a DC-DC boost converter, a DC-link capacitor of 15 mF, a grid-side inverter, three-phase step up transformers, and double circuit transmission lines, as shown in Fig. 1(a) and the single line diagram is shown in Fig. 1(b) . A DC-DC boost converter is used to control the output voltage of the PV plant in order to satisfy the maximum output power condition. This is done by controlling the duty cycle of insulated gate bipolar transistor (IGBT) switch of the converter. The grid-side inverter is utilized to control the DC-link voltage and terminal voltage at the PCC through a vector control scheme. A phase locked loop (PLL) is dedicated to detect the transformation angle from the three-phase voltages at the PCC. The output signals of the control scheme are converted to three-phase sinusoidal reference signals, which are compared with a triangular carrier signal of 1-kHz frequency to produce the firing pulses of IGBT switches.

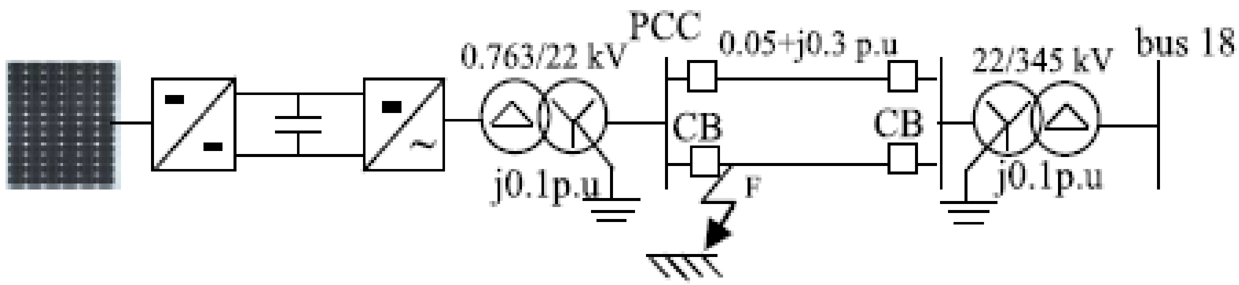

Fig. 1(a) Grid Connected PV Power Plant

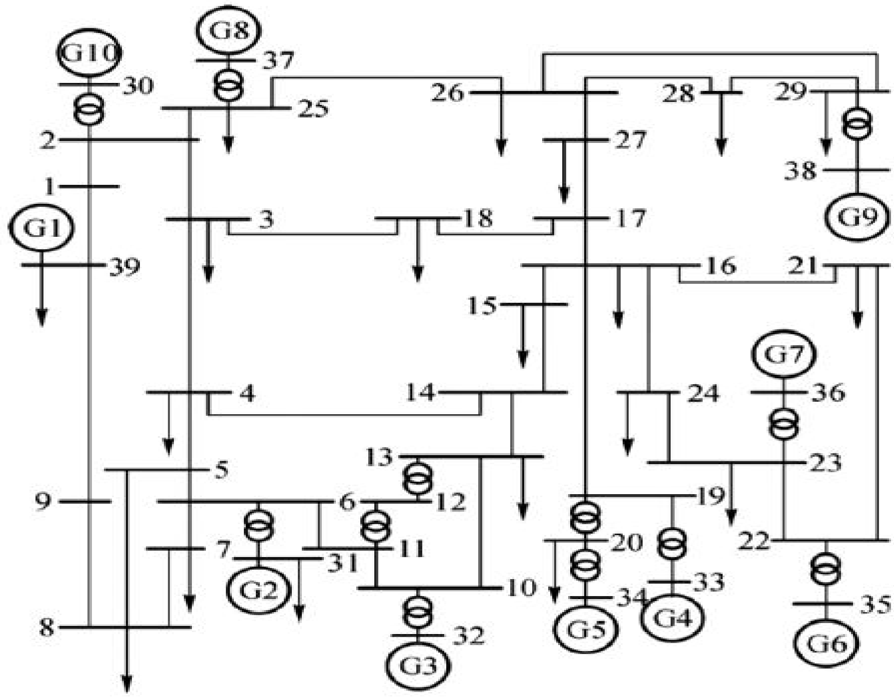

Fig. 1(b) Single line diagram of the IEEE 39-bus New England test system.

III. PROPOSED SYSTEM FOR 3LG TEMPORARY FAULT

The detailed model of a grid-connected PV power plant is presented in Fig. 2. The model involves a complete switching model of the power electronic circuits with the proposed adaptive control strategy for obtaining realistic responses. Fig. 2 represents the effectiveness of the proposed adaptive control strategy with optimal PI controllers, taking into account subjecting the system to symmetrical, unsymmetrical faults, and unsuccessful reclosing of circuit breakers due to the existence of permanent fault.

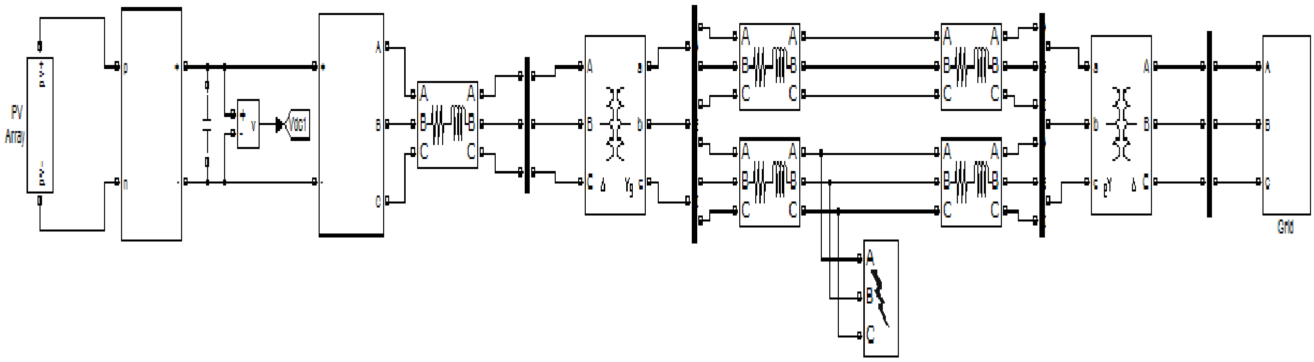

Fig.2 Proposed System for 3LG Temporary Fault

IV. SIMULATION RESULTS AND DISCUSSION

The proposed model was simulated using MatLab/Simulink tool. A three-line to ground (3LG) temporary fault takes place at time t=0.1s with duration of 0.1 s at fault point F. The Circuit Breakers (CB) on the faulted lines are opened at t=0.2s to clear fault. Then, the CBs are reclosed again at t=1s. The Voltage across PCC for 3LG fault is in Fig. 3. The real power out PCC is in Fig. 4. The reactive power out of the PCC is in Fig. 5. DC link voltage is in Fig. 6. The voltage at bus is in Fig. 7. Inverter currents for proposed controller are in Fig. 8. The voltage across PCC for 2LG fault is in Fig. 9. The voltage across PCC for LL fault is in Fig. 10.The voltage across PCC for 1LG fault is in Fig. 11.

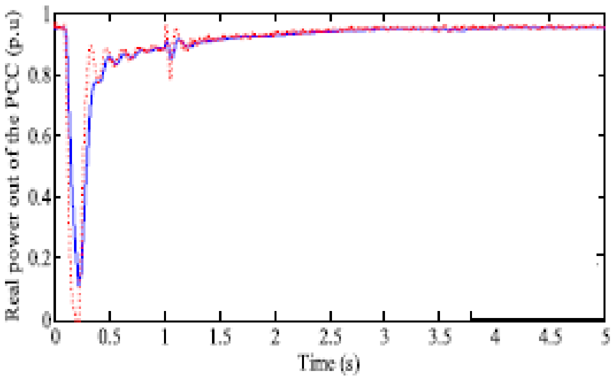

Fig. 4. Real power out PCC

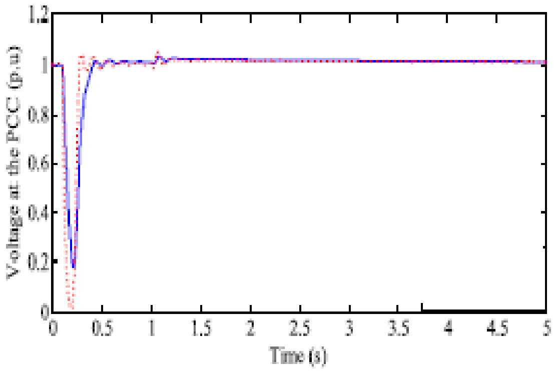

Fig. 3. Voltages across PCC for 3LG fault

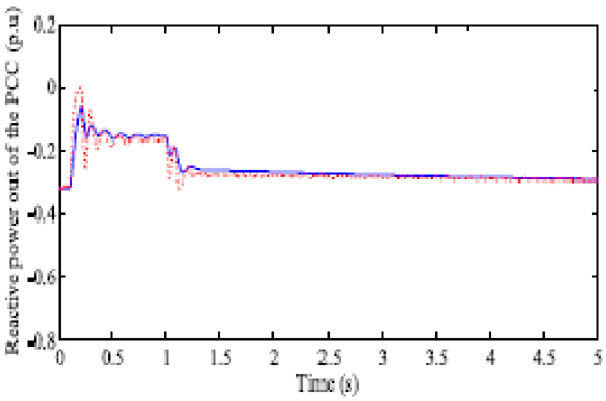

Fig. 5. Reactive power out of the PCC

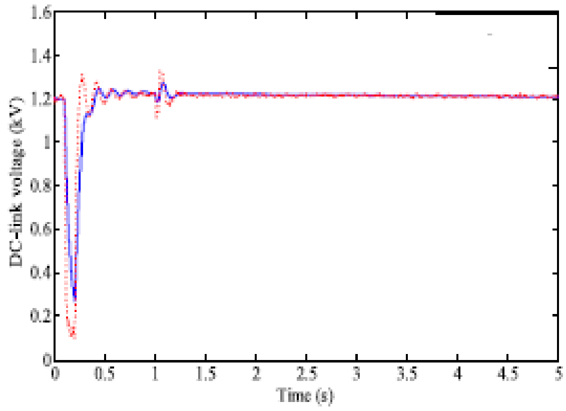

Fig. 6. DC link voltage

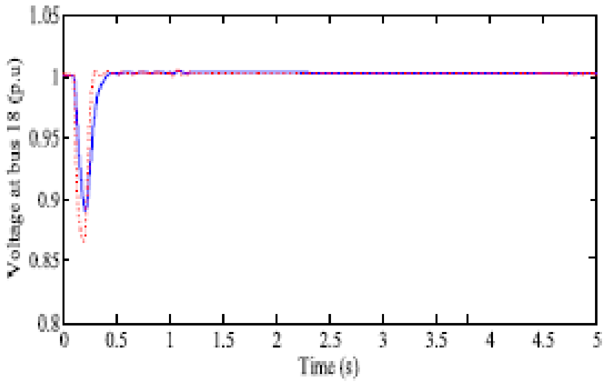

Fig. 7. Voltage at Bus

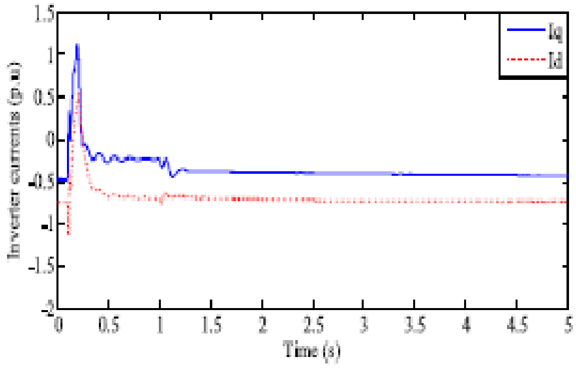

Fig. 8. Inverter currents for proposed controller

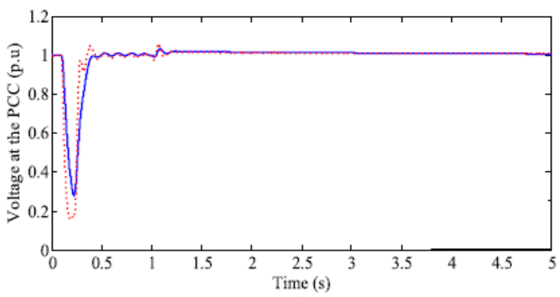

Fig. 9. Voltage across PCC for 2LG fault

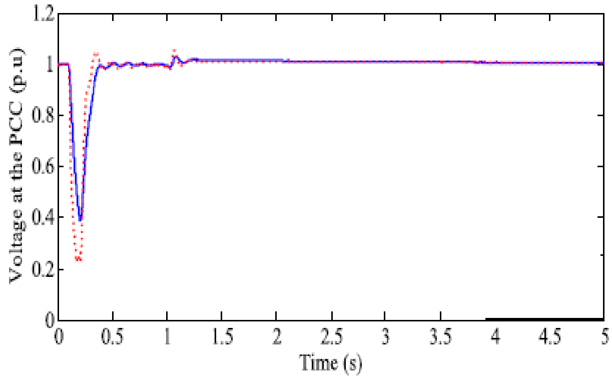

Fig. 10. Voltage across PCC for LL fault

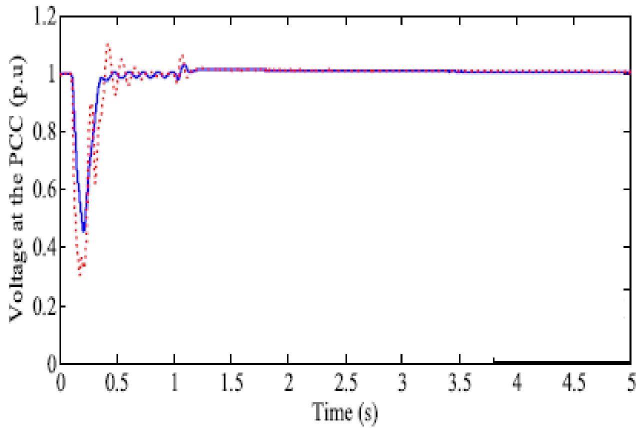

Fig. 11. Voltage across PCC for 1LG fault

V. CONCLUSION

In this paper, a novel application of the adaptive PI control strategy for enhancing the LVRT capability of grid-connected PV power plants. The proposed control strategy was applied to the DC-DC boost converter for a maximum power point tracking operation and also to the grid-side inverter for controlling the Voltage at PCC and DC link Voltage. The adaptive control strategy was used to update the proportional and integral gains of the PI controller online without the need to fine tune or optimize. The simulation results have proven that the system responses using the adaptive control strategy are faster, better damped, and superior to that obtained in the system with symmetrical 3LG temporary fault, different unsymmetrical faults and symmetrical 3LG permanent fault . It can be claimed from the simulation results that the LVRT capability of grid-connected PV power plants can be further enhanced using the proposed adaptive control strategy whatever under grid temporary or permanent fault condition. By this way, the PV power plants can contribute to the grid stability and reliability, which represents a greater challenge to the network operators.

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