

Power Flow and Stability Analysis of a PV-Based Distributed Generation System with UPQC

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Abstract— This paper describes the operation of a single-stage three-phase four wire grid-connected photovoltaic (PV) system operating through dual compensation strategy technique and also with the help of feed forward control loop (FFCL). Besides the injection of the active power into the grid, the PV system here acts as a unified power quality conditioner (UPQC), thereby helping suppress the load harmonic currents therefore helps in compensation of the reactive power. Hence better regulation, well-balanced and harmonics-free output voltages are fed to the loads. As the PV-UPQC is based on a dual compensation strategy technique, therefore series converter here does the role of the sinusoidal current source, whereas the parallel converter acts as a sinusoidal voltage source. Thus smooth transition can be achieved from the interconnected to the islanding operation modes vice versa thereby having no load voltage transients. Moreover, to overcome the problems associated with rapid solar irradiation changes, faster power balances which involve the PV array and the grid is obtained where the Feed Forward Control Loop acts on the generation of the series inverter current references. Hence the dynamic responses of both inverter currents and dc-bus voltage will be improved. Fuzzy logic controller is proposed in this paper for the mitigation of total harmonic distortion (THD). Detailed analysis involving the active power flow through the inverters are performed with proper understanding of the PV-UPQC operation. Simulation results are thus presented to evaluate performance of Dynamic Response.

Index Terms—Feed forward control loop (FFCL), neutral-point clamped (NPC) inverters, photovoltaic-unified power quality conditioner (PV-UPQC) system, universal filtering capability, Fuzzy logic controller.

I. INTRODUCTION

The two most important factors of any power delivery system today are Power Quality and the reliability of the system. The main concern for every consumer is the continuity of supply. Nowadays consumers not only require the continuous power supply but also quality in the power delivered to them. Therefore the power quality issue in distribution power systems are much increased. The power quality at the point of common coupling (PCC) with the utility grid is being governed according to certain standards of IEEE and IEEE-519 standard is most widely accepted.

Hence Researchers all over the world had worked on this for the improving the power quality. Although there are conventional solutions to the power quality issues, these conventional solutions use passive elements and may not always respond correctly because the natural conditions of the power system may change accordingly. So increased power capabilities, ease of control and low costs of the modern semiconductor devices have made power electronic converters affordable over a large scale. On the Flip side equipment made with semiconductor devices is appearing to be sensitive and even polluting too. Non-linear devices, such as power electronics converters increase the total reactive power demanded by the equivalent loads also injects harmonic currents into the distribution grid. As the presence of harmonic currents will be leading to additional losses in the

system as well as voltage waveform distortions leading to poor power quality. Demand towards the increase sensitive loads that require ideal sinusoidal supply voltages for their proper operation too increased. This increase leads to the interest in power conditioning technologies. Hence to handle the power quality within limits proposed by the required standards, it is therefore a need to include a sort of compensation. One modern solution that deals with both the load currents and supply voltage imperfections is the Unified Power Quality Conditioner (UPQC), which was first presented in 1995 by Hirofumi Akagi. This can help in compensating different power quality issues such as sags, swells, voltage imbalance, flicker, harmonics distortions etc. UPQC is a combination of both series and shunt active filters which are connected in cascade via a common dc link capacitor. The series active filter inserts a voltage, which is added at the point of the common coupling (PCC) hence maintaining load end-voltage to remain unaffected from any voltage imbalances. The main aim of a shunt active filter is in compensating the load reactive power demand thereby eliminating the harmonics from the supply current thereby regulate the common dc link voltage.

This Paper proposes the single stage three phase four wire grid connected photovoltaic system operating with the dual compensation strategy and feed forward control loop. The main objective of this paper is the improvisation of the power quality which has been a serious problem during these days. The main difference with this model and the other is that it uses PV system and as it is a conventional source of energy so the problem of pollution is further eliminated. The problems of voltage imbalance, voltage sags, transients, harmonic imbalances are further more decreased and it is the main aim of this model so as to improve the efficiency thereby decreasing the losses in the lines as well. It also uses an IGBT which can be used for firing the converter according to the reference voltages and it is very useful mainly because this model is for high power applications. So compared to MOSFET, IGBT is more preferable in order to obtain better results.

II. MODELING OF A PROPOSED TOPOLOGY

2.1 PV-UPQC System Analysis:

The UPQC is a customized power device that combines the series and shunt active filters connected back-to-back on the dc side and having a common DC capacitor which can be seen in figure 2.1. It employs two voltage source

inverters (VSIs) which are connected to a common DC energy storage capacitor. One of the two VSI is connected in series and other is connected in parallel.

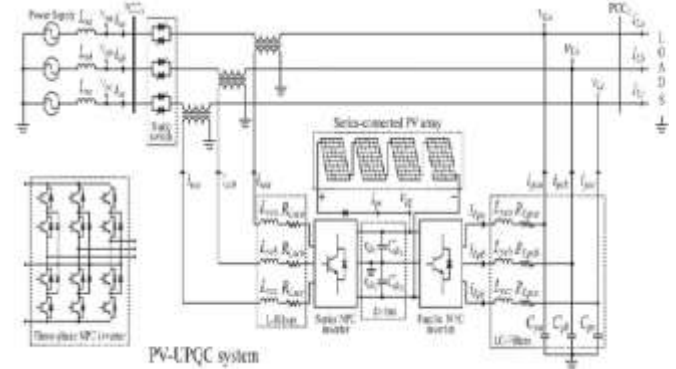


Figure 2.1- Power circuit diagram of a three-phase UPQC

The shunt active filter connected is mainly used for power factor correction and helps in compensating the load current harmonics and unbalances in the system. It also helps in maintaining constant average voltage across the DC storage capacitor. The shunt part of the UPQC consists of a VSI (voltage source inverter) connected to the common DC storage capacitor on the dc side and on the ac side it is connected in parallel with the load through the shunt interface inductor and shunt coupling transformer. The shunt interface inductor together with the shunt filter capacitor here is mainly to filter out the switching frequency harmonics produced by the shunt VSI. The shunt coupling transformer is used for matching the network and VSI voltages.

The series active filter compensation is done with injection of voltage in series with the supply voltages such that the load voltages are balanced and undistorted and their magnitudes are maintained at the desired level. This voltage injection is provided with the help of the dc storage capacitor and the series VSI. Based on measured supply and/or load voltages the control scheme generates the appropriate switching signals for the series VSI switches. The output voltages of the series VSI do not have the shape of the desired signals, but contain switching harmonics, which are filtered out by the series low pass filter. The amplitude, phase shift, frequency and harmonic content of injected voltages therefore can be controlled.

The design of UPQC power circuit includes the selection of the following three main parameters:

- shunt interface inductors;
- dc link reference voltage;
- dc link capacitor

for effective solving of the uncertainty in the problem. Fuzzy set theory is an excellent mathematical tool to handle the uncertainty arising due to vagueness. Understanding human speech and recognizing handwritten characters are some common instances where fuzziness manifests.

Fuzzy set theory is an extension of classical set theory where elements have varying degrees of membership. Fuzzy logic uses the whole interval between 0 and 1 to describe human reasoning. In FLC the input variables are mapped by sets of membership functions and these are called as “FUZZY SETS”.

Fuzzy set comprises from a membership function which could be defines by parameters. The value between 0 and 1 reveals a degree of membership to the fuzzy set. The process of converting the crisp input to a fuzzy value is called as “fuzzificaton.” The output of the Fuzzier module is interfaced with the rules. The basic operation of FLC is constructed from fuzzy control rules utilizing the values of fuzzy sets in general for the error and the change of error and control action. Basic fuzzy module is shown in fig.5

The results are combined to give a crisp output controlling the output variable and this process is called as “DEFUZZIFICATION.”

IV. SIMULATIONS AND RESULTS

A UPQC simulation model has been created in MATLAB/Simulink so as to investigate UPQC circuit waveforms and to know the dynamic and steady-state performance and voltage as well as current ratings.

The following typical case studies have been simulated and the results are presented .

1. Short duration three phase fault conditions.
2. Long duration three phase fault conditions.
3. Dynamic load and three phase fault conditions.
4. Harmonic compensation
5. DC link voltage regulation for the above conditions is also verified.

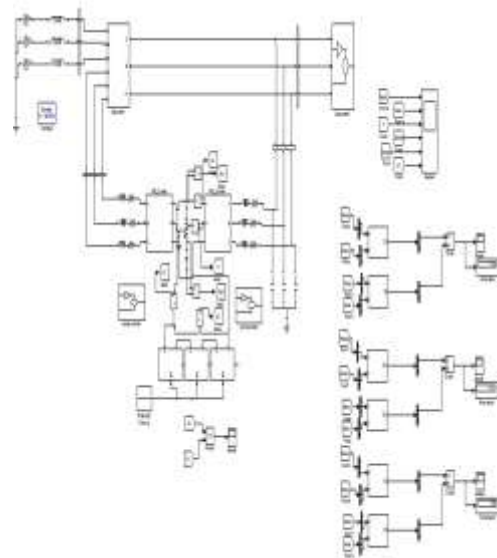


Figure 4.1:Simulation block diagram of the PV-UPQC system connected to conventional electrical distribution system

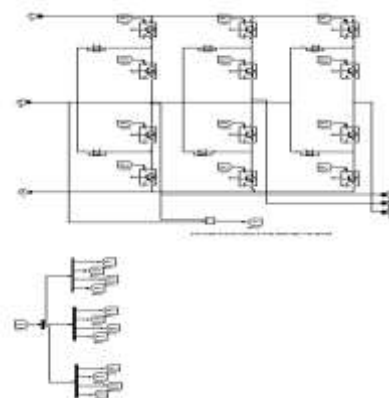


Figure 4.2 :NPC inverter configuration in matlab software

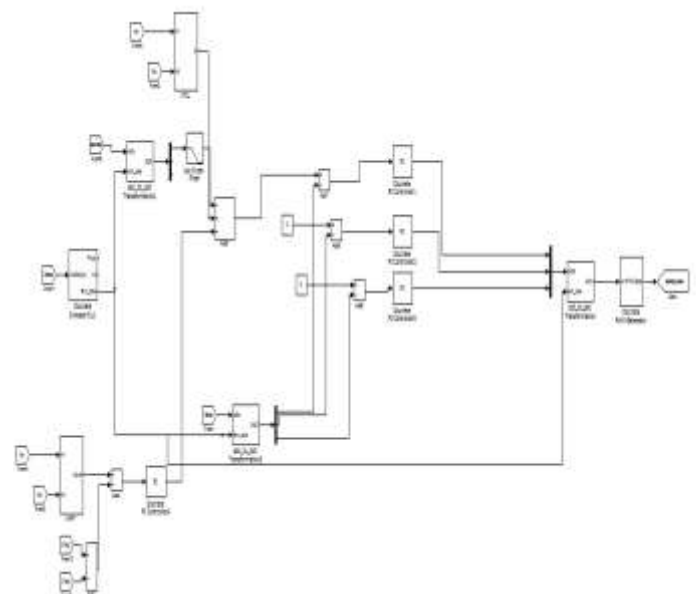


Figure 4.3 : Simulation block diagram of series converter

The simulation of the above is done for various cases the outputs obtained are shown in different cases from below

Case 1:

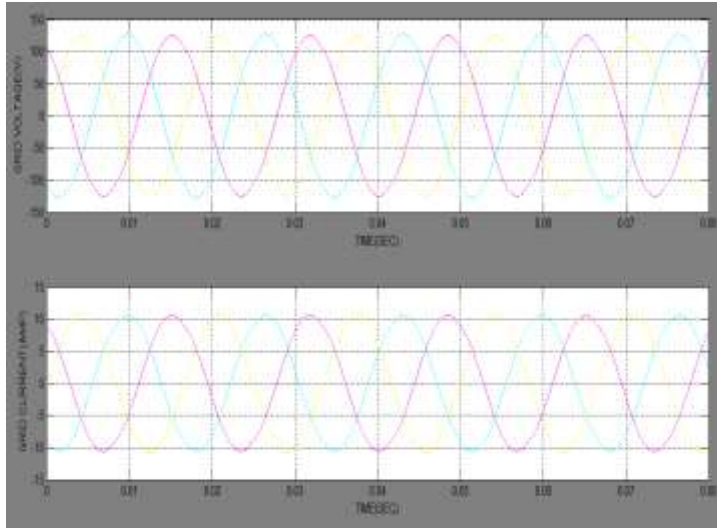


Figure 4.4 (a) grid voltages (V_{sa}, V_{sb}, V_{sc}) & (b) grid currents ($I_{sa}, I_{sb}, I_{sc}, I_{sn}$)

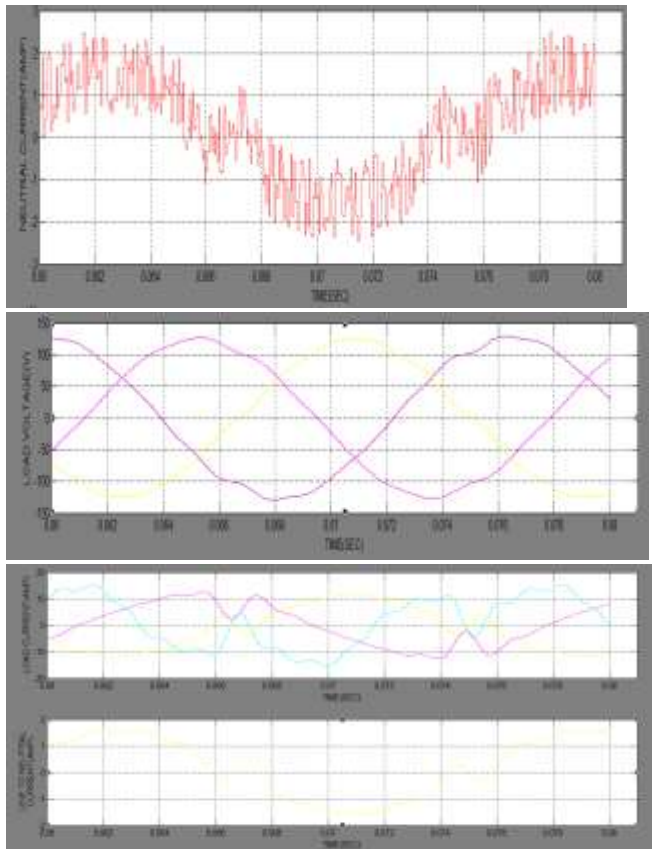


Figure 4.5 PV-UPQC performing active power injection into grid

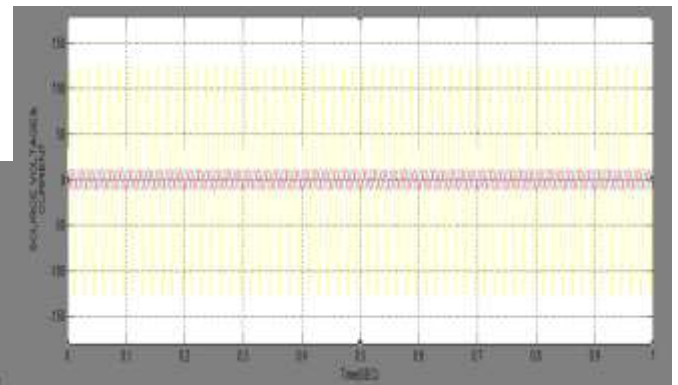
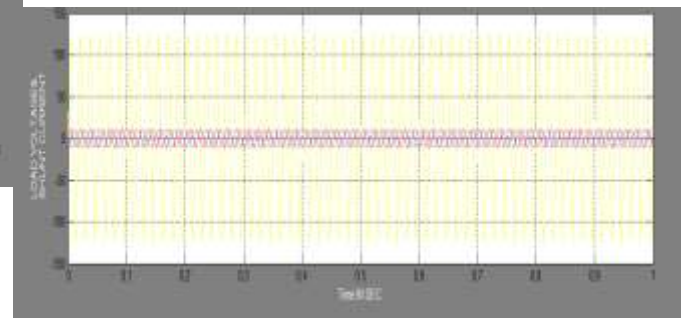


Figure 4.6 (a) grid voltage (V_{sa}) and grid currents (I_{sa}, I_{sb}, I_{sc})



(b) load voltage (V_{la}) and parallel NPC inverter currents (I_{pc}, I_{pb}, I_{pa}) PV-UPQC performing active power injection plus active power filtering with $P_{pv} < P_l$

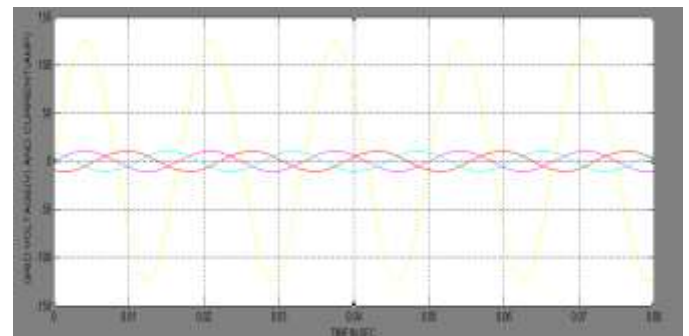
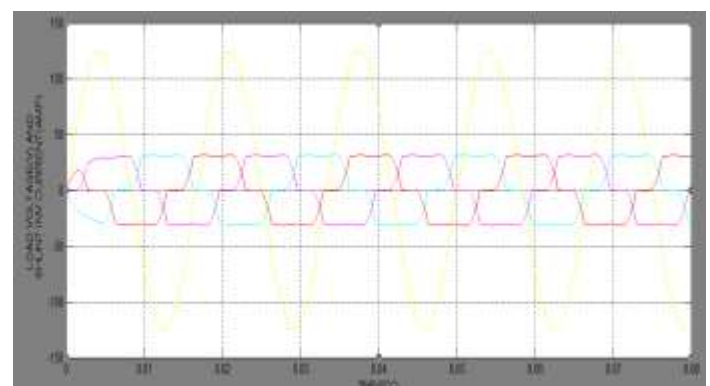
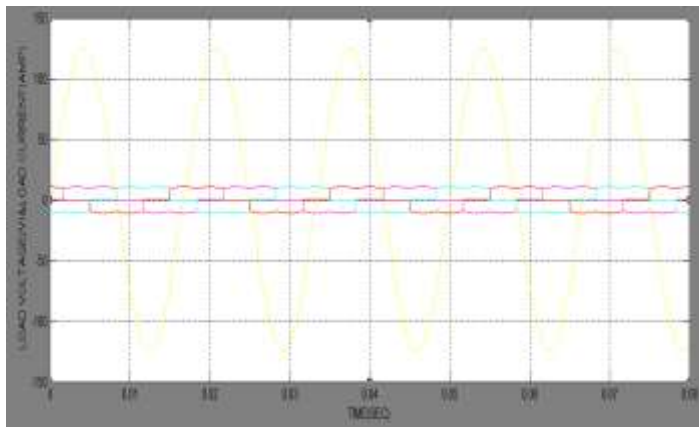


Figure 4.7 (a) grid voltage (V_{sa}) and grid currents (I_{sa}, I_{sb}, I_{sc})



(b) load voltages (V_{la}) and parallel NPC inverter currents (I_{pc}, I_{pb}, I_{pa})



(C)load voltages(Vla) and load currents currents(Ipca,Ipcb,Ipcc)

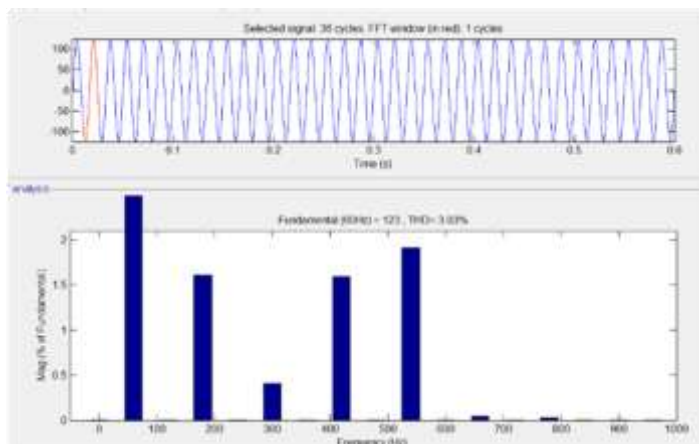


Figure 4.8 Dynamic response of using PI controller which indicates THD of 3.03%

V.CONCLUSION

This paper proposed an Single stage 3-phase 4-wire grid tied PV system performing the tasks of a UPQC operating with a dual compensating strategy and also FFCL. The system PV-UPQC was built by means of two back-to-back connected three level NPC inverters. Along with providing active power from the PV arrangement the PV-UPQC system was able to perform series-parallel power line conditioning. Hence both static and dynamic performances of the system were experimentally evaluated under disturbed grid voltage conditions including sags, unbalances and harmonics. Apart from series compensation suppression of load harmonic currents as well as compensation of load reactive power were carried out such that an effective power factor correction was achieved. The effectiveness of the FFCL acting on the series converter current references was properly evaluated under sudden solar irradiation changes. Fuzzy logic controller is proposed in this paper for the mitigation of total harmonic distortion(THD). The proposed PV-UPQC system hence

represents a promising solution to be applied to DG systems, as well as AC micro grids too.

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