

# Effective Photovoltaic Integration and Power Quality Improvement on Parallel Feeders using Dynamic Multi Converter Controller

K. Gunavardhan, I. Prabhakar Reddy, P. Sujatha

**Abstract:** Growing phase of industry and living standards in modern world brings drastic changes in modern utility structure and control. Gradually, green sources take place of traditional sources and aids the current utility power delivery for consumer loads. Green source and more sensitive loads integration to grid demands effective controller and reliable grid structure. In this paper, an effective grid structure with dynamic multi converter controller is proposed to alleviate disturbances in current and voltage on parallel feeders simultaneously. Soft computing based controller effectively integrates the photovoltaic green source and utilizes the power generated to aid the controlling action and to provide the desired power required on lines. Dynamic multi converter controller takes care of current and voltage disturbance alleviation, green source power integration and harmonics suppression on parallel lines under distorted & balanced and distorted & unbalanced source conditions. Performance of proposed Dynamic Multi Converter Controller with traditional and soft computing techniques is studied and compared in MATLAB/SIMULINK platform.

**Keywords :** Renewable sources, Power Quality, FACTS, Soft Computing methods, Multi Converters.

## I. INTRODUCTION

The concerns over global warming and drastic growth in day by day power demand raises the need of clean and abundant alternate source integration to grid [1-2]. This leads to integration of renewable sources, which best fit for the current needs. These renewable and more sensitive loads have an adverse effect on the utility and consumer [3-4]. An effective grid structure and efficient controllers are needed for current complex situation of utility to supply reliable power. In this paper an effective Dynamic Multi Converter Controller (DMCC) is proposed to improve quality of supplied power.

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Fig.1 shows an effective parallel grid structure along with integration of solar unit (SU) using DMCC. Here, DMCC performs real power delivery from SU to line, alleviates current and voltage disturbances on parallel lines, improves power factor and also efficiently suppresses voltage disturbances under balanced and unbalanced conditions.

## II. INTRODUCTION

DMCC is fed between distributed parallel lines. Parallel lines deliver power from individual sources  $S_1$  &  $S_2$  to sensitive load  $L_1$  & non linear load  $L_2$  respectively.  $V_{S1}$  &  $V_{S2}$  considered as source voltages,  $I_{S1}$  &  $I_{S2}$  considered as source currents, and  $I_{L1}$  &  $I_{L2}$  will be load currents. Proposed DMCC designed with three voltage source converters each of 3 legs. Among these, one converter act as shunt filter and remaining two acts as series filters.  $VSC_{se1}$  &  $VSC_{se2}$  be the Series converters and  $VSC_{sh}$  is Shunt Converter fed to Line-1. 3 voltage source converters fed at common DC link. To utilize SU effectively, it is fed to common DC link. SU will deliver required power to the DMCC and to line [5-6].

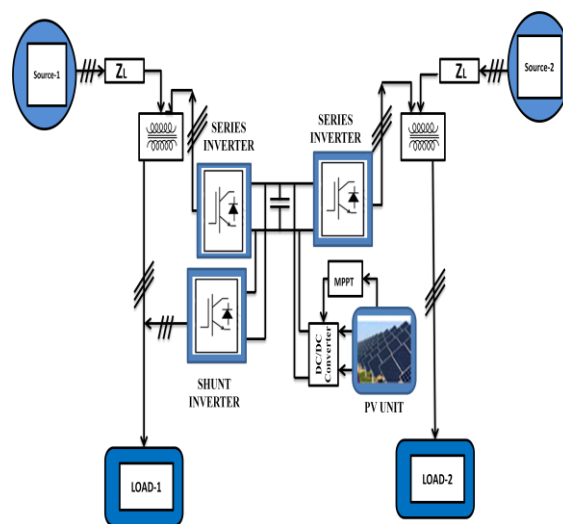


Fig. 1 Proposed DMCC System,

### A. Solar Unit

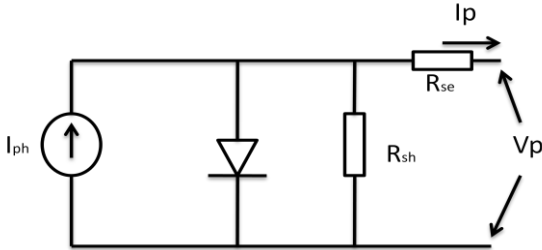
This renewable source is one of the abundant source available freely from nature. Here, SU delivers power needed by DMCC during current and voltage disturbance mitigation on parallel lines and remaining power will be fed to line. Among Several MPPT techniques, Perturbation & Observation (P&O) is widely preferred in existing systems due to its fewer parameters and simple process over Incremental conductance [7].

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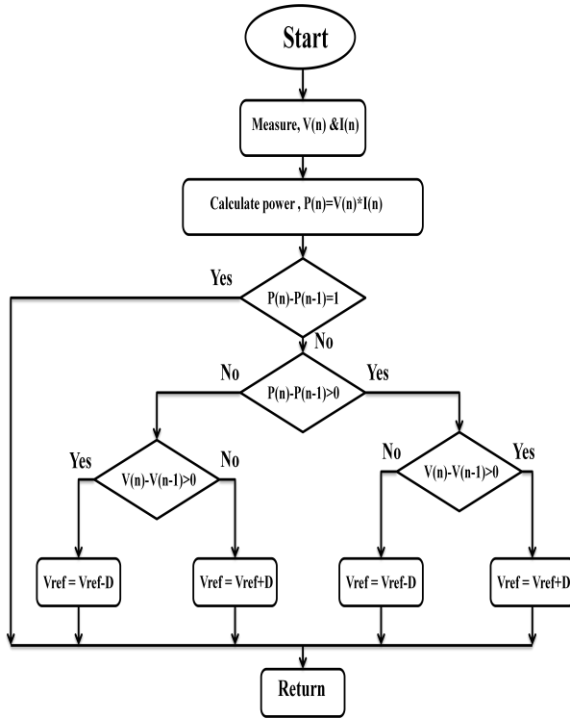
PV cell, Maximum Power Point Tracking (MPPT) unit and DC-DC converter are the parts of SU [8]. SU consist of 8X6 solar cells. Solar cell equivalent diagram is presented in Fig. 2 and P&O flowchart presented in Fig. 3. Current and Voltage from Fig. 2 given by

$$I_p = I_{sc} - I_{sat} \exp \left[ \frac{q}{AKT} (V_p + I_p R_{se}) - 1 \right] - \frac{V_p + I_{sc} R_{se}}{R_{sh}} \quad (1)$$

$$V_p = \frac{AKT}{q} \ln \left\{ \frac{I_{sc}}{I_p} + 1 \right\} \quad (2)$$



**Fig. 2 Solar Cell**



**Fig. 3 P & O MPPT Flowchart**

### III. CONTROL STRATEGY

The Control Methodology uses two control strategies to alleviate current and voltage disturbances. Shunt control strategy deals with disturbances in source currents and Series control strategy deals with voltage disturbance. Both Shut and Series Control strategies uses ANFIS [9-10] based modified DQ control technique for reference signal generation. 5 layer ANFIS structure preferred for effective error tuning over PI controller.

In Shunt control strategy final switching pulses generated from hysteresis current controller [11-12].

Whereas, in series control strategy, final switching pulses generated using sinusoidal pulse width modulation (SPWM)[14-15].

#### A. Shunt Control Strategy

Modified DQ Control Strategy utilized in shunt controller is presented in Fig. 4. In this, initially running time supply currents ( $I_{as}, I_{bs}, I_{cs}$ ) & voltages ( $V_{as}, V_{bs}, V_{cs}$ ), DC link voltages  $V_{dc}$  and load currents ( $I_{La}, I_{Lb}, I_{Lc}$ ) are sensed. Further load currents are transformed from abc frame to dq frame by using,

$$\begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos \varnothing & -\sin \varnothing & 1 \\ \cos(\varnothing - \frac{2\pi}{3}) & -\sin(\varnothing - \frac{2\pi}{3}) & \frac{1}{2} \\ \cos(\varnothing + \frac{2\pi}{3}) & \sin(\varnothing - \frac{2\pi}{3}) & \frac{1}{2} \end{bmatrix} \begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix} \quad (3)$$

$I_d$  and  $I_q$  components are allowed through Low pass filter to achieve constant DC components.  $I_{ddc}$  & the loss component are combined to generated dc link error signal. This signal is used for reference current  $i_{dref}$  generation. The loss ( $i_{ln}$ ) and direct axis ( $i_d^*$ ) components are shown given by

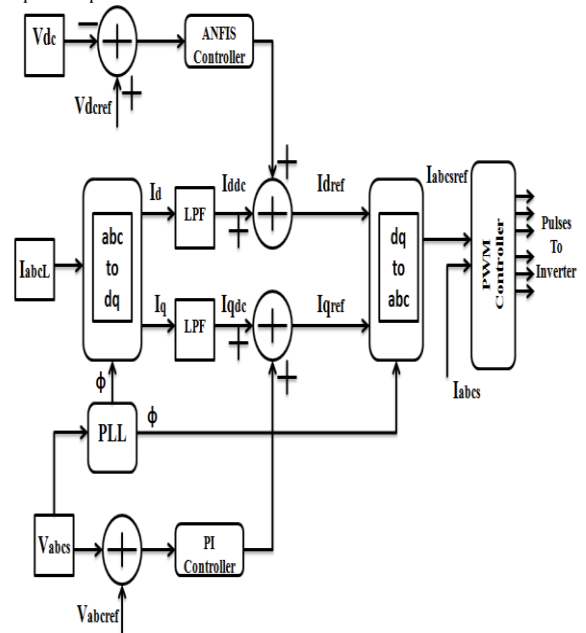
$$i_{ln} = i_{l(n-1)} + k_{pd} (V_{de(n)} - V_{de(n-1)}) + k_{id} V_{de(n)} \quad (4)$$

$$i_d^* = i_l + i_{ddc} \quad (5)$$

Similarly,  $i_{qdc}$  is summed up with tuned source voltage error for generating reference current  $I_{qref}$  as shown in Eqn. (10). Both references  $i_{dref}$  and  $i_{qref}$  transformed back to abc reference frame with the help of inverse park transformation.  $i_q^*$  is generated as follows,

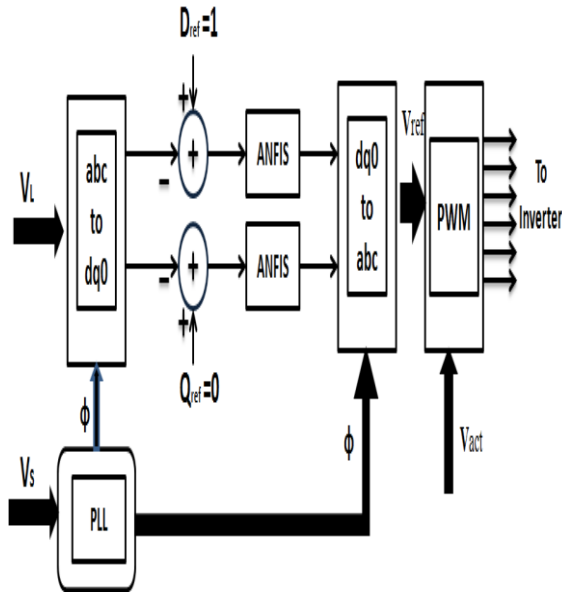
$$i_{qrn} = i_{qr(n-1)} + k_{pq} (V_{te(n)} - V_{te(n-1)}) + k_{id} V_{te(n)} \quad (6)$$

$$i_q^* = i_{qr} + i_{qdc} \quad (7)$$



**Fig. 4. Shunt Control Strategy**

**B. Series Control Strategy**



**Fig. 5. Series Control Strategy**

Series control strategy suppresses voltage disturbances like swell, sag and interruption. It also alleviates harmonics in load voltage. The series control strategy is presented in Fig.5. Primarily, supply voltage is converted into dq0 reference frame using,

$$V_{s1}^{dq0} = T_s V_{s1}^{abc} = V_{s1p} + V_{s1n} + V_{s10} + V_{s1H} \quad (8)$$

In the above,  $V_{s1H}, V_{s1p}, V_{s1n}$ , and  $V_{s10}$  are harmonic, positive, negative and zero sequence components resp. Objective is to achieve sinusoidal voltages to the load, so the dq0 reference frame of load voltage uses Parks transformation  $T_s$  and is given by,

$$V_{L1}^{dq0} = T_s V_{L1}^{abc} = \begin{bmatrix} U_m \\ 0 \\ 0 \end{bmatrix} \quad (9)$$

The suppressing dq0 reference voltage is given by,

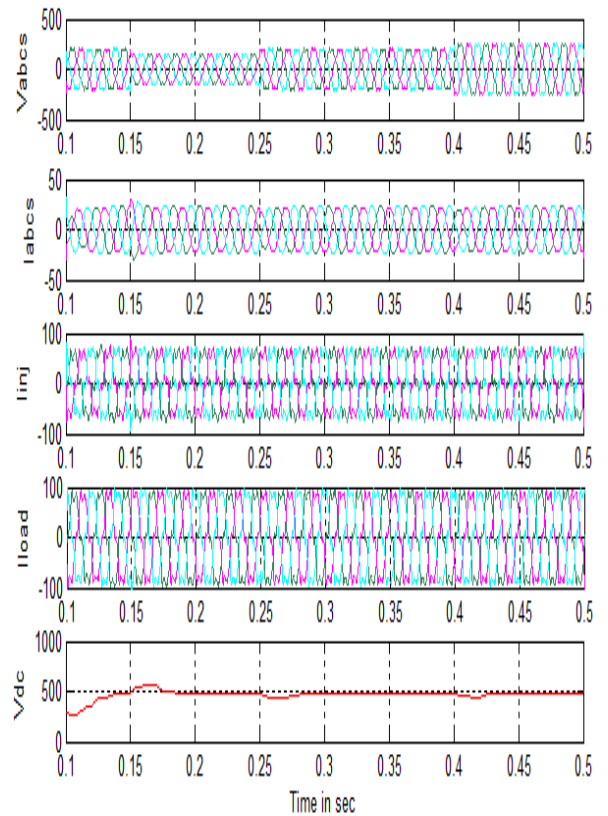
$$V_{dq0}^{ref} = V_{s1}^{dq0} - V_{L1}^{dq0} \quad (10)$$

The above suppressing voltage is again converted back to abc reference frame. Using SPWM the switching pulses are generated to alleviate load voltage disturbances.

**IV. RESULTS**

**A. Current Profile**

Harmonics injected due to non linear loads. Performance of DMCC is presented in Fig. 6. Here Modified DQ based shunt control strategy injects opposite currents to suppress current disturbances on line. Controller deactivated till 0.1 sec after that, the supply current becomes sinusoidal. Here Load Current is the summation of Source and SU fed Shunt current.



**Fig. 6 Supply Voltage & Current, Injected & Load currents and  $V_{dc}$  (b) Supply, Injected Load Voltages on Line-1**

**B. Voltage profile**

In Supply voltage, sag of 25% between  $0.15 < t < 0.25$  and swell of 25% between  $0.35 < t < 0.5$  were created. Series Control Strategy injects compensating voltage into Line-1 & 2 to suppress sag and swell, so that load-1 & 2 receives sinusoidal voltage, same is presented in Fig. 7 & 8 respectively.

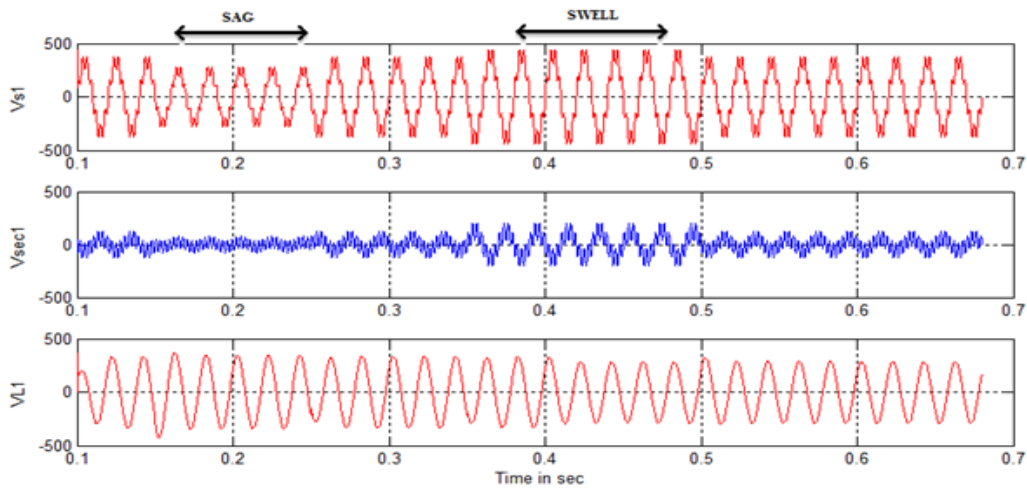


Fig. 7 Supply Voltage & Current, Injected & Load currents and  $V_{dc}$

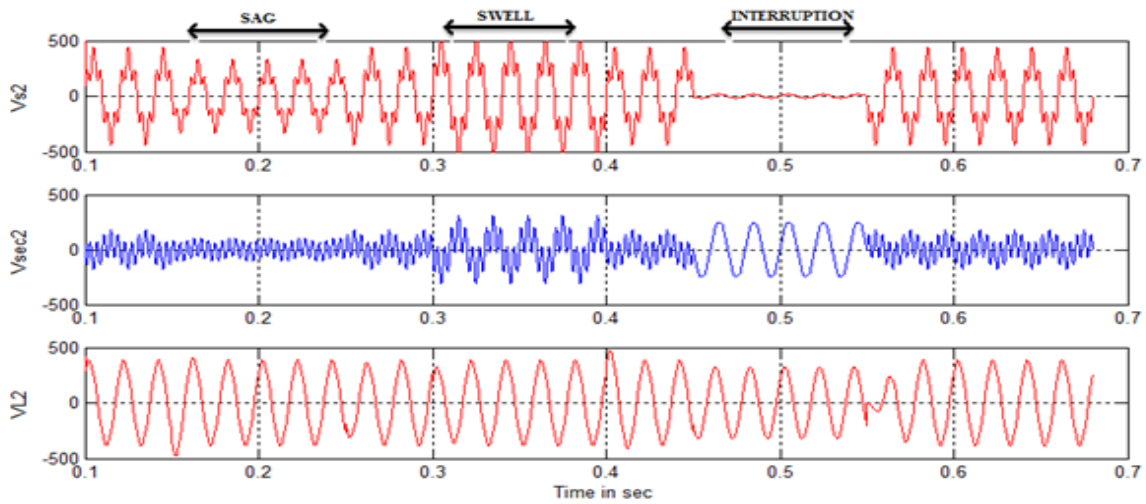


Fig. 8. Source, Injected and Load Voltages on Line-2

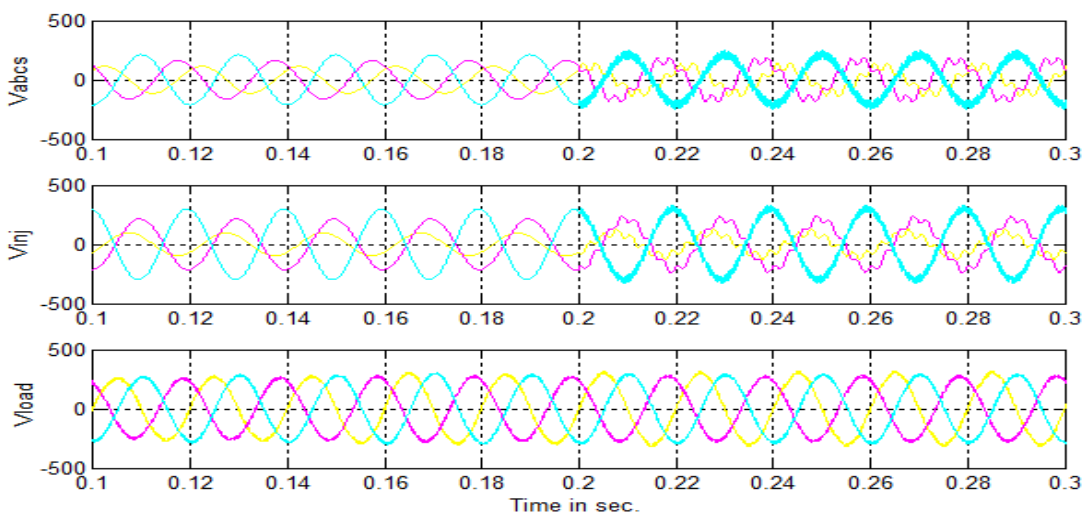


Fig. 9. Unbalanced and distorted voltages

Fig. 9 presents the performance of DMCC during distorted and unbalanced source voltage. Unbalanced sinusoidal voltages created from  $T = 0.1$  sec to  $0.2$  sec and distorted unbalanced voltages created from  $T = 0.2$  sec to  $0.3$  sec. Series control strategy injects required voltages to alleviate abnormalities. Due to this, load receives balanced sinusoidal voltages.

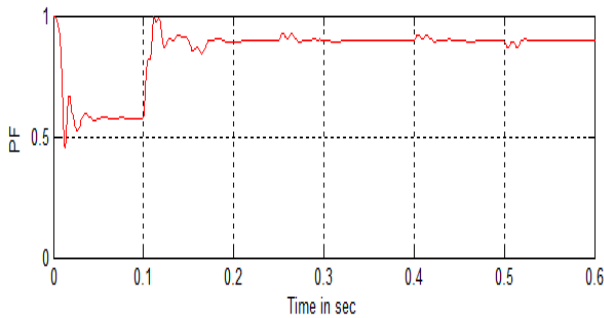


Fig. 10. Power Factorh Line-1

### 4.3 Power Profile

Fig. 11, shows real power delivered from source and SU fed shunt converter along with load power. Load real power is shared by source & SU.

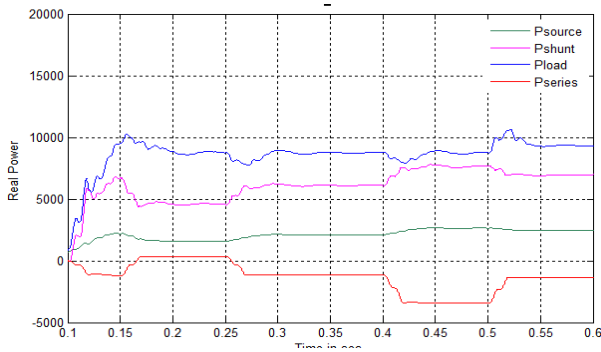
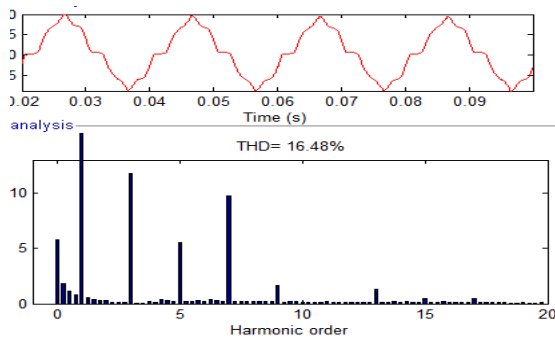


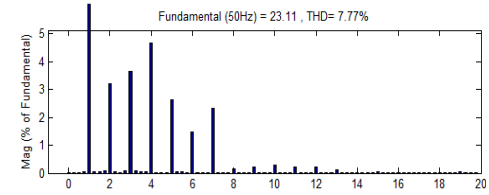
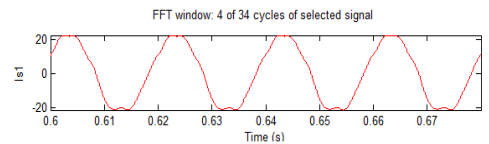
Fig. 11, Source, load, Shunt & Series Converters Real Power

### 3.4 Harmonics profile

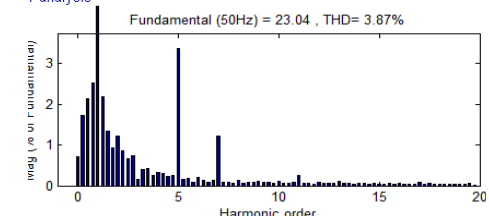
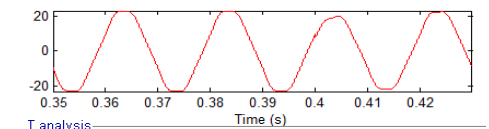
The harmonics alleviation in current & voltage is analyzed under without DMCC, with PI-DMCC and ANFIS-DMCC cases, same is presented in Fig. 12 & Fig. 13.



(a) % THD without DMCC

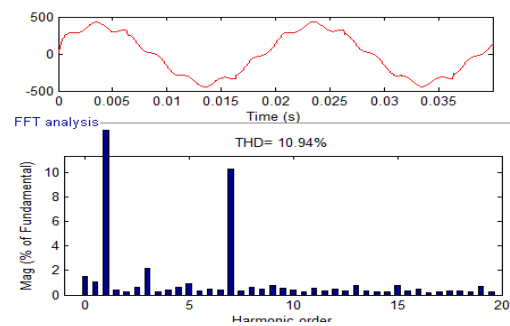


(b) % THD with PI- DMCC

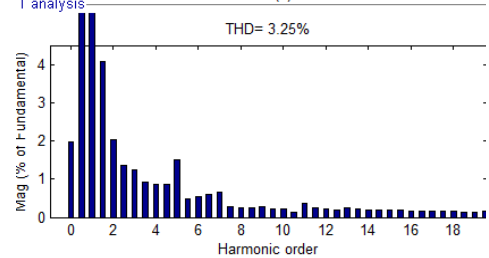
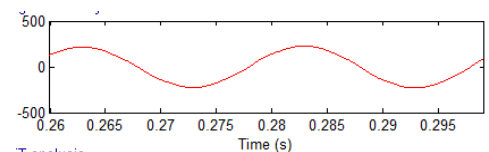


(c) % THD with ANFIS- DMCC

Fig. 12. Current %THD without DMCC, with PI-DMCC and with ANFIS-DMCC



(a) % THD without DMCC



(b) % THD with PI-DMCC



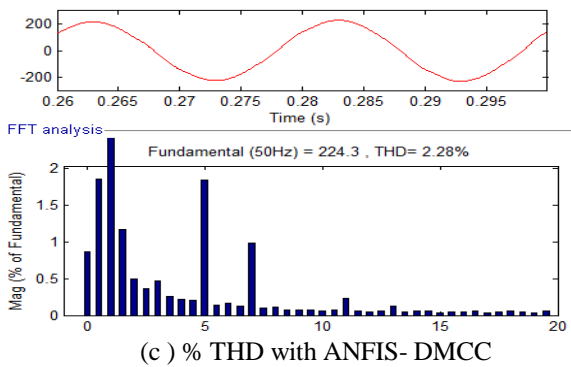


Fig. 13. Voltage %THD without DMCC, with PI-DMCC and with ANFIS-DMCC

Table 1 and Table 2 shows specifications and comparison of proposed systems with PI and ANFIS controller.

Table 1. Proposed System Specifications

S.No	Parameters	Ratings
1	Source voltage	3-Phase 380v,50 Hz
2	Source impedance, Line impedance $Z_L$	$R_s = 0.1\text{ohm}, L_s = 0.001\text{mH}$ $R_l = 0.02\text{ohms}, X_l = 0.1\text{mH}$
3	Load-2	$R_l = 10\text{ ohms}, X_l = 100\text{mH}$
4	Load-1	$R_l = 10\text{ ohms}, X_l = 0.03\text{mH}$
5	DC link Voltage	$V_{dc} = 600\text{V}$
6	Solar Cell	35V. 7.5A

Table 2. Comparison of Power Factor, % THD for Source current and Load voltage

Parameters	Without DMCC	With PI – DMCC	With ANFIS-DMCC
P F	0.58	0.91	0.91
%THD			
Source current( $I_a$ )	16.48	7.77	3.87
Load Voltage( $V_{la}$ )	10.94	2.58	2.26

## V. CONCLUSION

In this paper, ANFIS based modified DQ control method is proposed for DMCC. Proposed methodology compensates abnormalities in source current and load voltages. Modified ANFIS-DQ controller alleviates disturbances in current under source voltage abnormalities also. ANFIS-DQ controller achieves dominant performance in alleviation of current and voltage harmonics than traditional PI controller. In addition, DMCC effectively integrates solar unit power and utilizes optimally. Proposed controller achieves Total Harmonic Distortion of source current and load voltage on parallel lines within IEEE standards. PV unit delivers real power and supported DMCC controlling strategy.

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