International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-1, October, 2019

Double Boost SEPIC Converter based Multifunctional Grid Interactive Inverter for Renewable Energy Integration

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Abstract*: This paper deals with a multi objective control strategy to control the double boost sepic converter (DBSEPIC) based grid interconnected inverter using synchronous reference frame (SRF) control. In the process of renewable integration grid interactive inverter with suggested control can be economize as a 1) power allocation and control between the inverter and grid for load, 2) retrenchment of harmonics in source current, 3) reactive power compensation. In this proposed SRF control strategy there are two different types of controllers are used one is PI controller and another one fractional order sliding mode controller (FOSMC). The simplicity of PI controller and robustness of FOSMC utilised here. The performance of two controllers is compared in terms settling time, peak overshoot and THD through simulation results.

***Keywords* : Double boost SEPIC, SRF control, PI controller, FOSMC, renewable integration, Irradiance.**

I. INTRODUCTION

Nowadays environmentally well disposed power generation is fortunately running like solar and wind [1]. In the work on of solar power generation we need to ameliorate the efficiency using modern technology by overcome the technical problems [2]. Broad scale solar photovoltaic (PV) arrangements are generally connected to medium-sized voltage distribution grids, where power converters are needed to convert solar energy into electricity in like that a grid-interactive PV system [3], [4]. In PV system DC-DC converter, converts the unregulated DC to regulated DC because circuits work best with a stable and specific input [5]. Restrain the input to specific sub-circuits is important for accomplish design requirements. AC-AC conversion can be simply done with a transformer; however dc-dc conversion is not as simple. There are five main types of dc-dc converters. Buck converters can only reduce voltage, boost converters can only increase voltage and buck-boost, Cuk, and SEPIC converters can increase or decrease the voltage [6]. The traditional boost converter is used to step up the voltage levels but unable to supply high DC voltage gain [7], [8]. So in this paper, DBSEPIC converter is investigated because it is similar to the advantages of SEPIC converter like step up/down converter, it will improve the scope of operation of photovoltaic voltage, non inverting output and less current ripple [9]. But the DBSEPIC converter is quite different from the SEPIC converter in the case of DC voltage gain. In DBSEPIC converter high DC voltage gain compare to SEPIC converter. The main object of the grid connected inverter is active power transfer from renewable energy resources to the grid [10]. However the integration of solar energy, can also power quality difficulties to the grid [11]. Power sharing and voltage stability are an essential performance criteria in the function of grids. The integration of renewable energy resources is achieved by power inverter, modern control techniques are required. The SRF control contains the benefit that converts the ac quantities to dc at the stable state and hence traditional regulating controllers are used [12]. SRF control is most suitable here because of it realizing a zero steady state error with the help of P-I controller [13] and decreasing the settling time with FOSMC. Fractional-order sliding mode control (FOSMC) is suggested and researched for different areas in earlier years. Actually, FOSMC is an essential of conventional integer-order SMC [14]. By using fractional order, it is possible esteemed as an additional alterable parameter for designing of controller. Hence, the advantages of FOSMC in order that may be achieve good control performances [15]. Analyze simulation premeditated carried out with solar PV as renewable energy source and DBSEPIC topology is used to improve system efficiency from PV panels. The proposed control strategy with multifunctional grid interconnected inverter corroborate through simulation studies.

Revised Manuscript Received on October 30, 2019.
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II. PROPOSED MULTIFUNCTIONAL INVERTER TOPOLOGY

A. Structure of Dbsepic

DBSEPIC is a modified form of SEPIC converter, in which two SEPIC converters are connected side by side, one is upper SEPIC converter and another one is lower SEPIC converter. These two converters outputs combined together to given the input of proposed inverter. It used to maintaining constant DC input to the inverter at various conditions of irradiation and temperature.

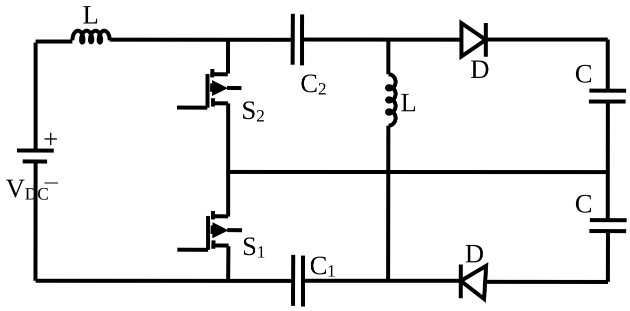

Figure1: basic circuit diagram of DBSEPIC

Here by using radial base network, pulses given to the switches of DBSEPIC converter. A radial base network is an artificial neural network that uses radial basis function the output of the network is a linear combination of radial basis functions of inputs and neuron parameters. Radial base function networks have many uses, including function approximation, time series prediction, classification and system control.

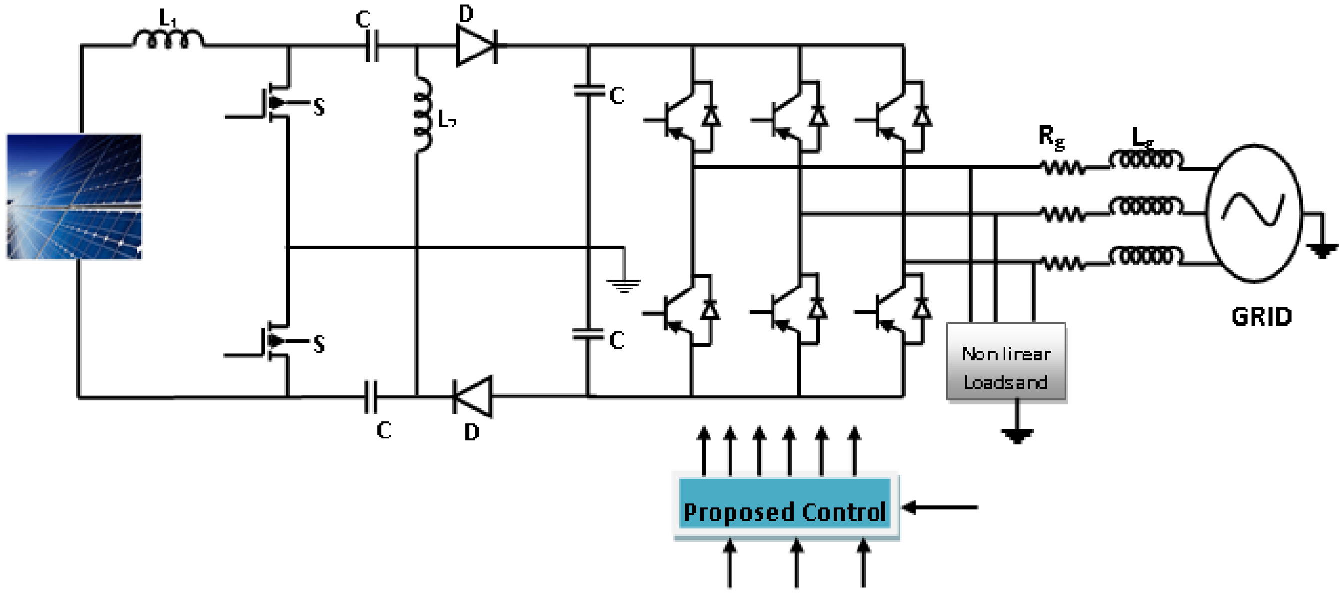

Figure2: PV energy conversion with proposed topology

B. Grid Interactive Inverter

PV connected multifunctional grid interactive inverter schematic diagram is shown in figure (2). In this proposed topology IGBT/DIODE based three phases six pulses inverter is used. To test the multifunctional aspects of grid connected inverter with SRF control strategy is proposed in this paper, unbalanced load is connected between the inverter and grid.

III. CONTROL ARCHITECTURE

In SRF control, the grid currents and voltages are transforming to reference frame that rotates synchronously with grid voltage by means of this the control variables become DC values thus filtering and controlling can easily achieved. Multi objectives of grid connected inverter are achieved by proper reference current needs to be extracted. This extracted reference current is based on the sensed load current, grid connected inverter output current and DBSEPIC converter output voltage (V_{DC}). The difference between V_{DC} and reference DC voltage V_{DC}^{*} is taken as an error e(t), it can Grid voltages equations . Basic control logic is shown in fig.3. be used to control the active current of generating units (i_{G}^{*}). The secondary function of grid connected inverter is to offer harmonic compensation, by using low pass filter (LPF) the harmonic components of the non-linear load current (i_{ldh})is extracted and used as a reference current for the grid connected inverter. Non linear load (i_{ldh}) is added with i_{G}^{*} to form the d-axis reference current (i_{cd}^{*}) for the grid interactive inverter. Therefore i_{cd}^{*} transfers the data concerning the active current that has to be injected from the generating units to the grid and also the non-linear load current harmonics are compensated by the reference current and it is given by Eq. (1).

$$i_{cd}^{*}=i_{G}^{*}+i_{ldh} \quad (1)$$

The q-axis component (i_{lq}) is responsible to compensate the entire load reactive power demand. Hence, the Eq. (2) shows the q-axis current of grid connected inverter. In similar manner, 0-axis component responsible to neutral load current given by Eq. (2).

$$i_{cq}^{*}=i_{lq}\ ;\ i_{c0}^{*}=i_{l0} \quad (2)$$

Retrieval Number: A1875109119/2019©BEIESP
DOI: 10.35940/ijeat.A1875.109119
Journal Website: www.ijeat.org

Published By:
Blue Eyes Intelligence Engineering
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$$V_a = V_d^* \sin\omega t + V_q^* \cos\omega t + V_0 \quad (3)$$

$$V_b = V_d^* \sin(\omega t - \tfrac{2\pi}{3}) + V_q^* \cos(\omega t - \tfrac{2\pi}{3}) + V_0 \quad (4)$$

$$V_c = V_d^* \sin(\omega t + \tfrac{2\pi}{3}) + V_q^* \cos(\omega t + \tfrac{2\pi}{3}) + V_0 \quad (5)$$

d-q-0 reference equations

$$V_d = \tfrac{2}{3}[V_a^* \sin\omega t + V_b^* \sin(\omega t - \tfrac{2\pi}{3}) + V_c^* \sin(\omega t + \tfrac{2\pi}{3})] \quad (6)$$

$$V_q = \tfrac{2}{3}[V_a^* \cos\omega t + V_b^* \cos(\omega t - \tfrac{2\pi}{3}) + V_c^* \cos(\omega t + \tfrac{2\pi}{3})] \quad (7)$$

$$V_0 = \tfrac{1}{3}(V_a + V_b + V_c) \quad (8)$$

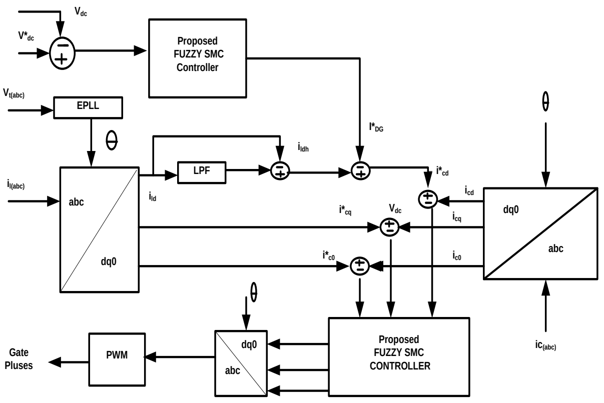


Figure3: Block diagram of control logic.

i) PI controller:

PI controller is employed to terminate the steady state error outcome from P controller. However, in requirements of the speed of the response and entire steadiness of the system, it has opposing effect. PI controller is mainly used in regions where speed of the system is not a matter. Since P-I controller has no capability to indicate the further errors of the system it cannot reduce the rise time and eradicate the oscillations. If applied, any quantity of I assurances set point overshoot. In proposed control topology we used two P-I controllers with different K_P and K_I values. In first PI controller K_P =0.5, K_I =50 and in second P-I controller K_P =0.006, K_I =3 for desired output.

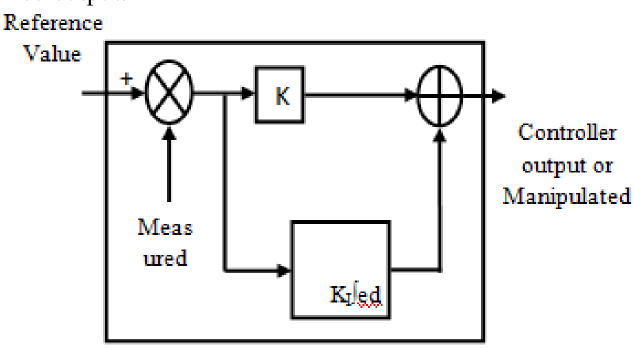


Figure4: Simple circuit of PI controller.

ii) FOSMC:

FOSMC is the utilization of sliding mode control with fractional sets or sliding surface accordant to a fractional order dynamic, or both. In this control strategy 0.8 fractional order is used for desired output. Compare to the P-I controller it has quick dynamics with less overshoot and settling time. Design analysis of FOSMC is given below

Error e(t) is given as

$$e(t) = V_{DC}^*(t) - V_{DC}(t) \quad (9)$$

Derivation of e(t) with respect to time is

$$\dot{e}(t) = -ae(t) - bi_q(t) + \emptyset(t) + \delta(t) \quad (10)$$

$$\emptyset(t) = a\,V_{DC}^*(t) + c(t) + \dot{V}_{DC}^*(t) \quad (11)$$

$$\delta(t) = \Delta a V_{DC}(t) - \Delta b i_q(t) + \Delta c(t) \quad (12)$$

Where $\delta(t) \in R^+$

In this analysis fractional order sliding surface is taken as

$$S_f = K_p e(t) + 0^{D_t^r} \quad (13)$$

Here K_p is a positive value, and $0^{D_t^r}(.)$ is fractional order integral (0<r<1).

Where, we taken control law follows

$$\dot{S}_f = -wS_f - K_{S_f}\,\text{sign}(S_f) \quad (14)$$

Where w, $K_{S_f} \in R^+$, sign(.) is the sign function.

$$\text{sign}(S_f) = \begin{cases} 1, & S_f > 0 \\ 0, & S_f = 0 \\ -1, & S_f < 0 \end{cases}$$

In ideal condition $\delta(t)$=0, from equations (10), (11), (12) and (13) we get

$$\dot{S}_f = \frac{dS_f}{dt} = 0^{D_t^{r+1}} e(t) + K_p(-ae(t) + \emptyset(t) - bi_q(t)) \quad (15)$$

According to equation (14) and (15) we get $i_q(t)$ is equals to

$$(bK_p)^{-1}\left[0^{D_t^{r+1}} e(t) + K_p\emptyset(t) + (w-a)K_p e(t) + w0^{D_t^r} e(t) + K_{S_f}\,\text{sign}(S_f)\right] \quad (16)$$

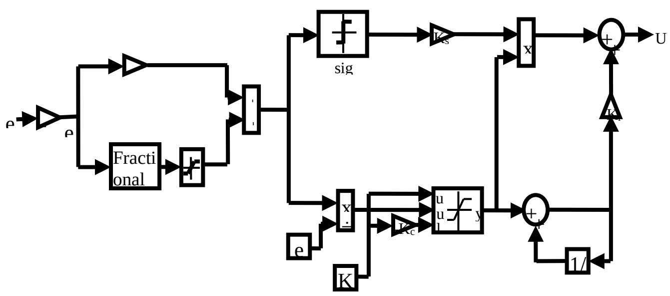


Figure5: Simple circuit of FOSMC.

iii) DC link voltage controller design:

Voltage controller transfer function is represented by $G_{dc}(s)$ for control loop, in terms of $V_{DC}(S)$ and $i_c(s)$ is given as

$$G_{dc}(s) = \frac{V_{DC}(S)}{i_c(s)} = K_{DC}\frac{1}{sC_d} \quad (17)$$

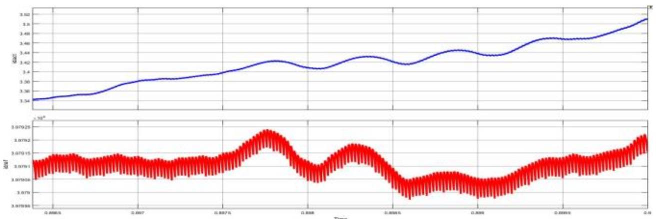
Where K_{DC} is constant related to d-axis current and C_d is dc link capacitor similar way design of current control loop , after mathematical calculation, the open loop transfer function of voltage control loop is given as,

$$G_{V,ol} = K_p K_i \left(\frac{1+sT}{s^2 TC_d}\right)\cdot\left(\frac{1}{T_{eq}s+1}\right) \quad (18)$$

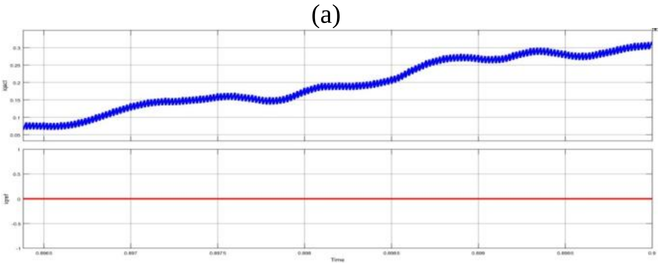
Where $T = \frac{K_p}{K_i}$; K_i and K_p are the integral and proportional gains of the voltage controller, T_{eq} is the equivalent time delay. By using these functions voltage control loop is obtained.

IV. SIMULINK RESULTS AND ANALYSIS

Performance of the suggested multifunctional control strategy is verified through simulation studies by using matlab/simulink results of proposed system is observed at different conditions as follows i) sudden change in input of PV array ii) sudden increment in load. Two different controllers performance is compared at these two conditions with respect to settling time, overshoot and THD.

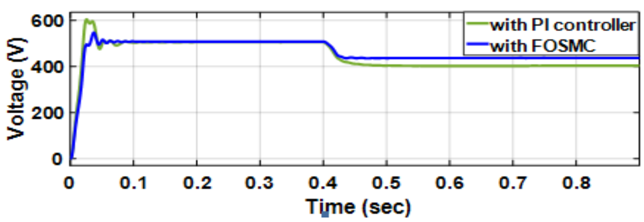


(a)

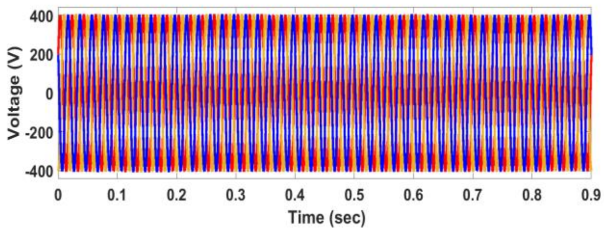


(b)

Figure6: Reference tracking accomplishment of FOSMC (a) active current (b)



(a)



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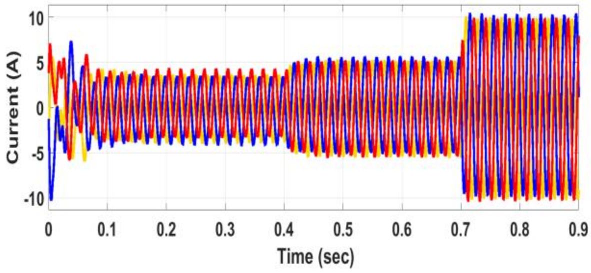
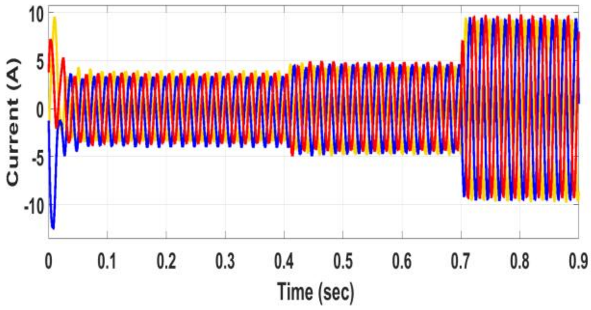
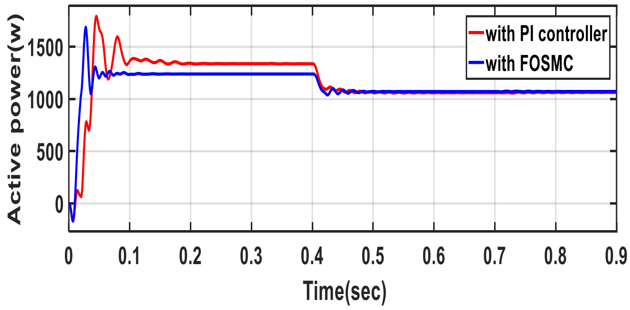


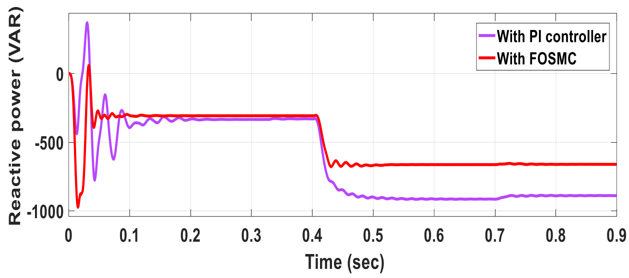
(c)



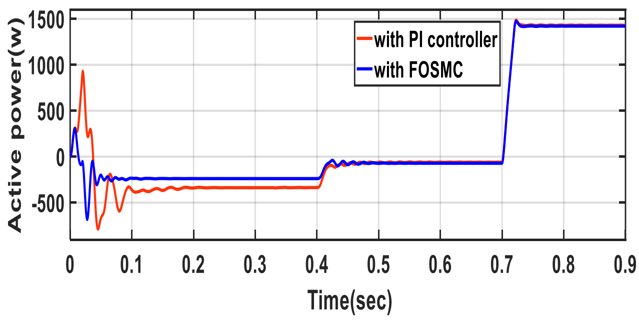
(d)



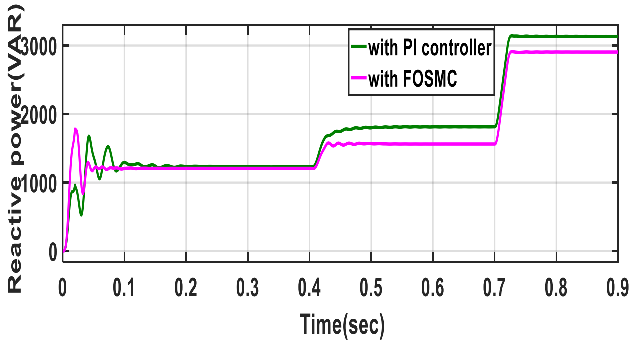
(e)



(f)



(g)

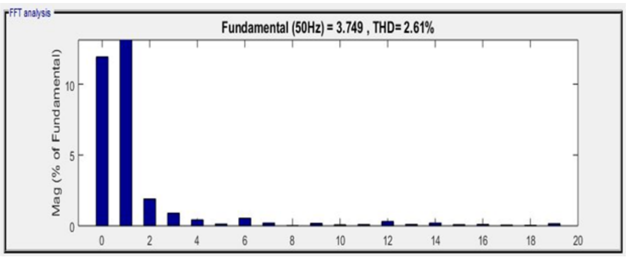


(h)

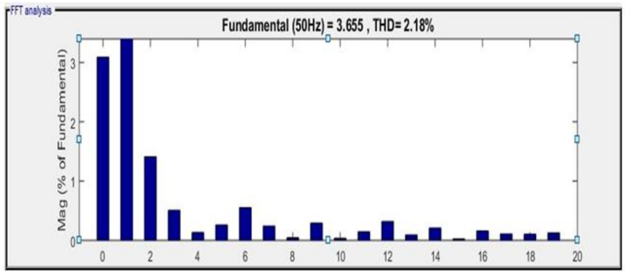
Figure7: Simulation results of developed control strategy. (a) DBSEPIC output voltage (b) grid voltage, (c) grid current with PI controller, (d) grid current with FOSMC, (e) inverter active power, (f) inverter reactive power, (g) grid active power and (h) grid reactive power.

In this process of simulation study, the various conditions are considered as follows time t=0s-0.4s, the input (irradiance) of PV array is 2100 w/m^2 at this situation load is 1KW, in this time period inverter supplies the 1200W active power with quick settle possible in FOSMC compare to the PI controller shown table.1. Here grid connected inverter is 1000W supplies to the load and remaining 200W is given to the grid. During t=0.4s-0.9s irradiance decreased to 1000 w/m^2 in the same condition at the t=0.7s load is suddenly increased to 2.5KW. In this time period inverter supplies the 1100W and grid supplies the remaining 1400W to the load. The operating performance of DBSEPIC at two different controllers with different irradiance conditions shown in Fig. 7(a) from this output voltage of DBSEPIC is fast settled with FOSMC(at 0.06sec) compare to PI controller(at 0.1sec). The active current and reactive current tracking accomplishment of the FOSMC is shown in Fig. 6. The proposed controller offers better tracking performance during various uncertainties.

Voltage of the grid is constant at 400V in each condition irrespective of time shown in Fig.7(b). Grid current consumption is increased when irradiance is decreased and load increased, wave forms of PI controller and FOSMC shown in Fig. 7(c), (d). Active power and reactive power sharing at different conditions shown in Fig.7(e)-(h).



(a)



(b)

Figure8: Grid current THD analysis (a) with PI controller and (b) with FOSMC. the units for each quantity that you use in an equation.

THD analysis of grid current with two different controllers shown in a Fig.8(a),(b), in this THD of FOSMC is 2.18 and THD of PI controller is 2.61. From table (1) we know FOSMC is better settling time 0.06 sec and overshoot 9% compare to PI controller settling time 0.1 and overshoot is 16%. From above calculations FOSMC is better performance is possible compare to PI controller.

Table1: Performance comparison between PI controller and FOSMC

controller	Settling time(sec)	Overshoot (%)	THD
PI controller	0.1	16	2.61
FOSMC	0.06	9	2.18

V. CONCLUSION

In this paper, multi-objective control strategy for grid connected inverter using PI controller and FOSMC has been proposed. In the proposed control method, the simple structure of PI controller and robust nature of FOSMC was utilized effectively to improve the dynamic performance of the system during various conditions like irradiance and load changes. In each condition FOSMC is performed better compare to PI controller with respect to settling time, peak overshoot and THD.

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