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Performance investigation of ANFIS and PSO DFFP based boost converter with NICI using solar panel

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Abstract

The modeling and development of the boost DC to DC converter with Partial Swarm Optimization with Distinctive Feed Forward Propagation (PSO-DFFP) controller for hybrid power systems including solar panels. The static and dynamic investigation of the developed PSO DEEP controller is presented. The PSO-DFFP controller has been designed to improve the operating efficiency and reduces the input converter current ripple. The PSO DFFP controller is developed and performance is compared with ANFIS and FLC. The developed system reduces the switching losses and voltage drops in switching modes. The designed system is demonstrated and developed with 200W, 100kHz model. The investigation results is exposed that the developed PSO DEEP system is an acceptable for SOLAR applications.

Keywords: PSO-DFFP, Solar, Converter, CI (Coupled Inductor), ANFIS,PV

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1. Introduction

The solar power is easily accessible in environment, and exceptional to it is unlimited accessibility, it is turn into the accepted competent of renewable energy sources. It has considered a recognizable source of economical renewable sources because it is low in operating costs and free environmentally issues. The costs of solar modules are high, the generation of power using solar systems, especially grid-tied types, has been feasible because of their inherent life time benefits. Still, photovoltaic power is not in the system. Module, MPPT (Maximum Power Point Tracking) usually works with an inverter or converter to improve the use of large arrays. Regularly, the fossil fuels are used to reduce the power demand. The emerging issues along with extended air pollution, disappearance of fossil fuels incorporate with RES which is utilized as a power supplier. However, the energy sources absorbed from solar panel is decreased because of different climate conditions and restricted shadows in urban places. Due to that the solar panel efficiency is decreased, to improving the efficiency of the system arrangement cost is more (Gu et al., 2013).

Bei et al. (2014) has been created the excessive achieve inter leveled converter with photo voltaic panel the use of sliding mode technique was presented. The performance of the converter and controller was introduced and simulation results presented. Stalin and Sivakumaran et al. (2016) have been described and developed bidirectional converter used to be developed with conventional PI controller and Fuzzy logic controller. The overall performance of the conventional and FLC controller was demonstrated with soft switched inverter. The performance of the system was evaluated (Farahani, 2007). Adib and Farzanehfard (2019) have been developed the ultra capacitor bank batteries for unidirectional soft switched inverter was introduced. The pulse with modulation control procedure was developed and presented design of capacitor bank analysis. The static and active consideration of the unidirectional converter was not presented.

Baggio et al. (2018) demonstrated the ZVS converter with isolated inter leave. The phase shifted PWM techniques was developed and presented. The soft switching mode of operation of the converter was presented. The inverter presentation was studied in sliding mode technology. The zero voltage switching converters with non-isolated buck converter was presented (Balestrino et al., 2002, Cheng et al., 2007, Zhang and Eberle, 2009, Banu and Moses, 2016). Zhang et al. (2007) developed the unidirectional DC to DC converter with soft switching mode. The converter system is operated with full load condition and it was produced 98 percentage efficiency of the system. The SPWM based ZVS converter was developed and demonstrated (Liu and Li, 2006; Xiao and Xie, 2008; Nagarajan and Madheswaran M., 2011; Nagarajan and Madheswaran, 2011; Kumar and Nagarajan, 2016). The proposed solar systems are in phase with the utility voltage and fabricate a sinusoidal output current that is provided to the benefit. A demonstrated model is distended and checked to validate the presentation of this developed solar system. Xiao and Xie (2008) stated that rooftop photovoltaic systems mean that their generated power is not observed and are not normally visible to system operators.

The method of a data analysis driven approach was proposed that uses a small number of measurements at a representative site to estimate invisible solar power generation (Liu and Li, 2006; Nagarajan and Madheswaran, 2011a,b,2012; Nagarajan et al., 2012; Kumar and Nagarajan, 2016). Prasad et al. (2016) has been developed the DPFM system for solar systems was presented. The transient and dynamic invigoration of the converter was not analyzed (Nagarajan and Madheswaran, 2012; Nagarajan and Mathiyalagan, 2012; Nagarajan et al., 2013; Umadevi and Nagarajan, 2020; Lakshmi and Nagarajan, 2021; Nagarajan et al., 2021, 2022). Nagarajan et al. (2022) have developed the hybrid intelligent controller using RPF technique was presented. The static and dynamic performance of the system was present and compared with existing system (Nagarajan et al., 2022a,b; Tharani and Nagarajan, 2020).

In the above literature examination of static and dynamic execution of the proposed DC to DC power soft switched converter is predominant in high power utilization. The proposed PSO DEEP controller for soft switched based DC to DC power converter with NICI (Non-Isolated Coupled Inductor) has been executed with various performances. The performance of the proposed system and efficiency is upgraded using this proposed technique. The full load and no load conditions the proposed system is produced with good efficiency. The dynamic performance and static performance of the proposed system is presented. The proposed converter model is demonstrated with 200 W, 100 kHz and the experiment results are presented. The simulation and experimental results are evaluated and presented.

2. Developed Soft Switched Boost Converter with NICI

Figure 1 shows that the proposed PSO DEEP system. The solar panel generated a various voltages of radiance and temperature. The boost converter is used to control the MPPT with solar panel. VSI is received the maximum boosted voltage from the controlled converter. The boost converter received the power from AC three phase loads. The converter output voltage is applied to the filter (LC), the filters used to reduce the harmonics in the output voltage.

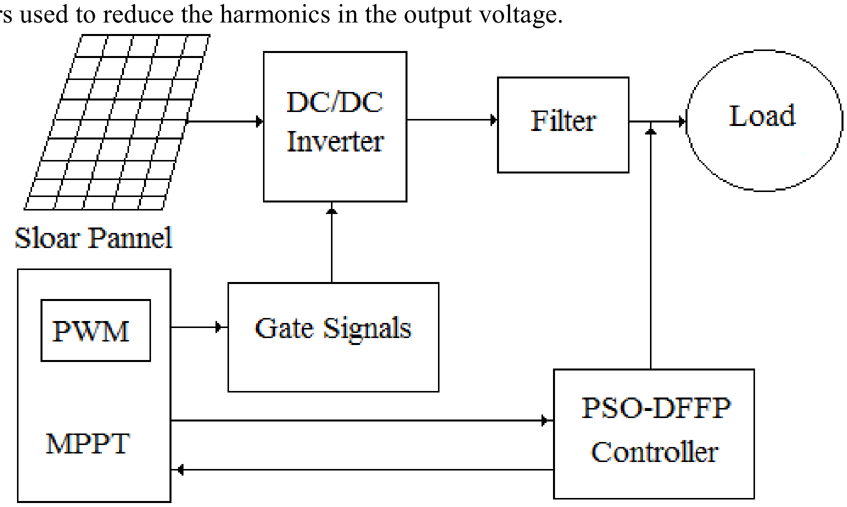


Figure 1. Developed Block Diagram PSO-DFFP System

A boost converter can be used for a DC output that is not controlled by a controlled DC input to convert to the needed volume volts, its circuit diagram illustrated in Figure 1.They usually turn this voltage off and then the stored energy is transferred to a DC voltage and transfer it to a controlled voltage output during the current that causes the energy to flow across the inductor or transformer. The V_0 (output voltage) of the converter is controlled by the gate pulses on and off time. This can be attained by a power switches whose element dissipation is negligible. The total converter output voltage and regulation of the systems is controlled by PWM signals.

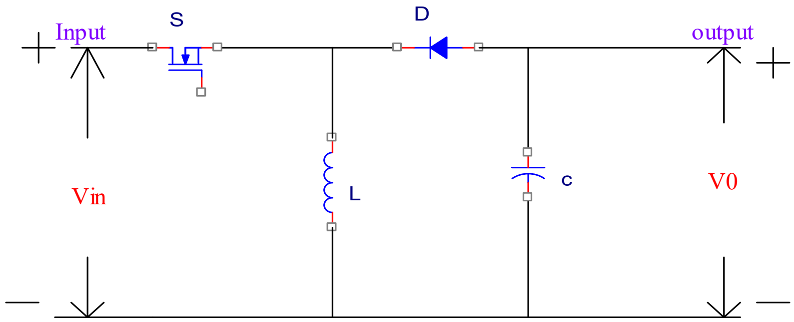


Figure 2. Circuit diagram of the developed DC to DC converter

When the switch S is off mode, in total system is separated with two sides that are input to the input side of the output side. A closed loop containing a trigger input will cause current to flow through the current circuit. When the switch S if OFF, the total current flow of the system is raises linearly. At the same time interval, the high-inductance voltage is passed to the load side. The diode D is in OFF state at this time of interval. There will be a closed loop and load and the power is saved in the L and RC. Therefore, the capacitor charging in the current load region of the inductor decreases linearly.

Figure 2 shows the operating principle of developed DC to DC converter. In CCM (Continuous Conduction Mode) of operation converter, $V_L = V_{in}$ while the S switch is ON condition and the S switch is in OFF condition, the output is $V_L = V_o$. The Avg. voltage across L is zero.

$$V_I t_{on} + V_{out} t_{off} = 0 \ldots \tag{1}$$

Voltage ratio is

$$\frac{V_{out}}{V_I} = -\frac{\tau}{(1-\tau)} \ldots. \tag{2}$$

And the corresponding current rate,

$$\frac{I_{out}}{I_I} = \frac{(1-\tau)}{\tau} \ldots. \tag{3}$$

The duty ratio " τ " is values obtained in 0 and 1, at the time the converter output voltage is various from low level to higher level degree. CCM and DCM which is specified by,

$$L_1 = \frac{(1-\tau)^2}{2\tau} \ldots \tag{4}$$

A mutant vector is generated by

$$X_i^{'G} = X_a^G + F(X_b^G - X_c^G) \tag{5}$$

where,

$a \neq b \neq c \neq i$

$X_a^G X_b^G X_c^G$-Random vectors

F is a mutation factor with the range [0,1]

Thus the general structure of a PSO-DFFP is depicted in Figure 3

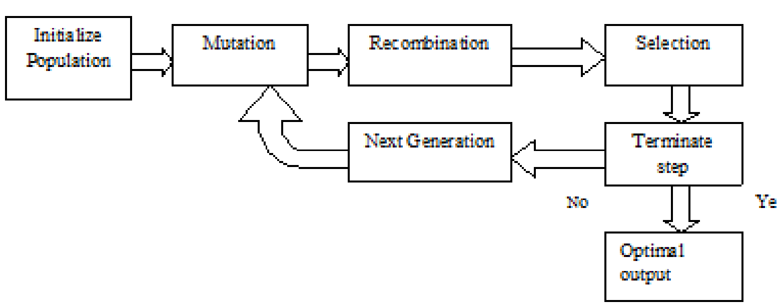


Figure 3. General Structure of PSO-DFFP

3. Results and Discussion

3.1 Design of PSO-DFFP Controller

Table 2 presents the simulation Parameters of the developed boost Converter with NICI values. (Umadevi and Nagarajan, 2020)

Table 2: Simulation Parameters

Parameters	**Output**
Maximum Power	200Watts
Switching Frequency	100kHz
Short circuit voltage	80v
Current at maximum power	5.29A
SC Current	5.29A
OC Voltage	38.5V
Inductor	100µH
τ	3
C	10µF
Output C	47µF

The Hybrid PSO-DFFP trained network shown in Figure 4. For a D-dimensional explores space, the location of the i[th] element is instead of as $X_i = (x_{i1}, x_{i2}, x_{iD})$. Every particle controls a remembrance of its earlier better position $P_i = (p_{i1}, p_{i2} \ldots p_{iD})$ and a $V_i = (v_{i1}, v_{i2} \ldots v_{iD})$ velocity the length of every dimension. The two basic equations that govern the work of PSO DEEP are the velocity vector and the position vector given by:

$$V_i^{(t+1)} = \omega \times V_i^{(t)} + c_1 \times r_1 \times \left(P_i^{best} - X_i^{(t)}\right) + c_2 \times r_2 \times (G^{best} - X_i^{(t)}) \tag{6}$$

The following equation calculates the inertia weight ω.

$$\omega = \omega_{max} - \frac{\omega_{max} - \omega_{min}}{iter_{max}} \times iter \tag{7}$$

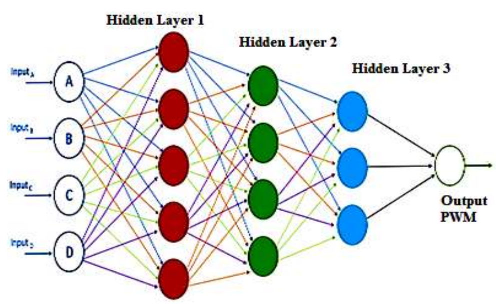


Figure 4. Hybrid PSO-DFFP trained network

The Pi^{best} and G^{best} direction is measured and a new velocity is found in the current explore end. Each particle efforts to transfer from its present position to different position by using below in equation

$$X_i^{(i+1)} = X_i^{(t)} + V_i^{(t+1)} \tag{8}$$

3.2 Proposed PSO-DFFP

It started as a customary particle swarm algorithm, and we found the speed of the swarm particles as given in below. Then we find a more advantageous position from the current particles and the reformed position. Then it will cross and select according to the PSO-DFFP rules. Continue this process until you stop certain conditions being met,

Step 1: Start the training process

Step 2: The inputs at this stage are temperature, SOLAR panel safety and load. This assignment will be maintained pending sufficient data has been collected to total offline instruction.

Step 3: Set the association right connecting to I/P node and O/P node. The choice of typical area can be found from earlier requirements, or calculated from PSO DFFP:

$$w_{kj}^L = min\{x_{kj}^K\} \tag{9}$$

$$w_{kj}^u = max\{x_{kj}^K\} \tag{10}$$

Step 4: Obtain the forecasted data.

Step 5: estimate the first collect middle of each cluster.

$$Z_k = \{z_{k1}, z_{k2}, \ldots, z_{kn}\} \tag{11}$$

$$z_{kj} = \frac{w_{kj}^L + w_{kj}^U}{2}, for\ k = 1,2 \ldots n_c; j = 1,2, \ldots n$$

Step 6: study the i^{th} instruction model and its cluster number p.

$$X_i^p = \{x_{i1}^p, x_{i2}^p, \ldots, x_{in}^p\}, p \in n_c \tag{12}$$

Step 7: Use the developed technique to estimate the detachment to the training model piX and the k^{th} cluster as follows:

Step 8: Upgrade the weights of the p^{th} and the k^{*th} clusters as follows:

(a) Upgrade the middle of the p^{th} and the k^{*th}clusters.

$$Z_{pj}^{new} + \eta\left(x_{ij}^{p} - z_{pj}^{old}\right) \quad (13)$$

(b) Up the weights of the p^{th} and the k^{*th} clusters.

Step 9: Repeated the steps 3 to 6.

Step 10: Stop, the total error reached determined value. or else, go back to step 3.

The proposed controller reached the steady state output voltage in quick time at the desire value. In the MPPT function, output current and output voltage attainted interval at 0.02s to avoid unwanted noise in electric system. The proposed PSO-DFFP operation should control converter switching pulse MPPT tracking time. Figure 4 shows the PSO-DFFP training Flowchart of the controller.

Fig. 5 represents the PSO DFFP controller training chart. PSO DEEP controller produced the switching pulse for the converter operating switches. The difference between output and reference voltage are calculated and error signal given to the PSO DEEP controller. The change in error signal is generated and it's given to the operating switches.

3.3 Simulation Results

This developed PSO-DFFP with MPPT method utilizing MATLAB 2017a software is to be used and simulate the system. The photovoltaic module characteristic the effect of the partial shadow state utilizing an arbitrary source to form a series of attached photovoltaic cells with radiation. The temperature of the photovoltaic module is kept stable at 25 degree C during the MATALB simulation. The shadow-free voltage module has a radiation-considerable exterior at 1000W / m^2. The radiation on the marked voltage block is changing beyond the standard from 0 to 1000W / m^2.As cycles of duty are reinitialized for each shift in radiation medicine, fast-tracking speeds and nearly zero latency fluctuations in MPP are achieved from computing power. Fig 6 shows the simulation circuit of the boost converter.

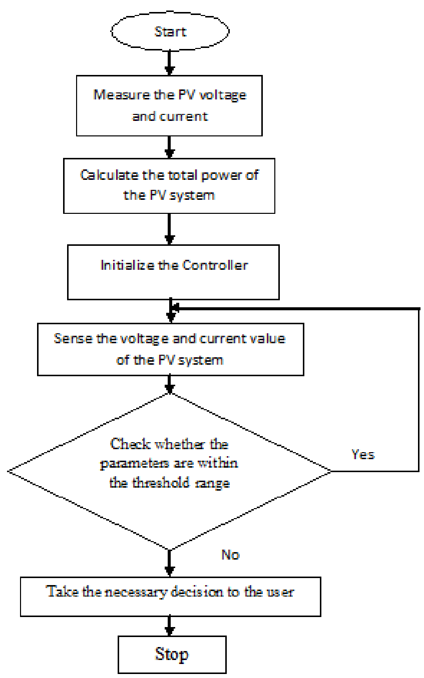


Figure 5. PSO-DFFP training Flowchart

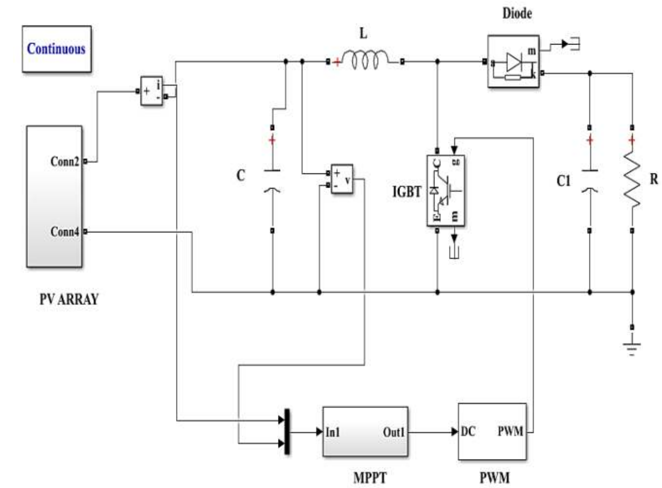


Figure 6. Simulink model for the boost converter

Figure 7 shows the PSO DEEP controller output voltage and output current of the boost converter with CI. The ANFIS controller output is settling (t_s) time at 9 msec with rejection of overshoot and the PSO DFFP controller output is t_s in 5.9 msec. without distractions and satisfactory of static performance and dynamic presentation. The PSO DFFP Controller performances compared with ANFIS controller and tabulated.

From the results made for purpose of comparison, it used to be decided that the PSO DFFP system is more reliable with ANFIS controllers. The developed PSO DFFP system attained quick reference value with fewer oscillations in the change of load conditions. It is clearly shows the Figure 8, the converter output voltage is near to the reference voltage with change in load conditions in the PSO DEEP controller.

Figure 8 presents the Output current and output voltage with load disturbance. The load variations are applied at 60mSec and 80mSec, the proposed system performance and ANFIS controllers are presented in Figure 8 (a). It is absorbed from the figure 8 (b) the PSO DEEP controller produced better execution in the disturbances of load conditions. The percentages overshoot and settled time is better while boost converter worked in PSO DFFP. In the load distribution conditions the PSO DEEP controller gives the less percentage overshoot and less steady state error.

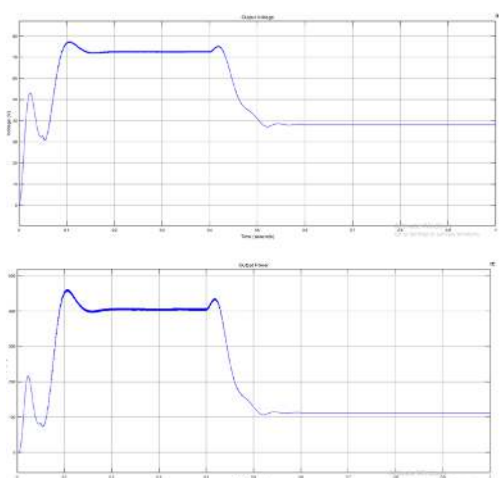
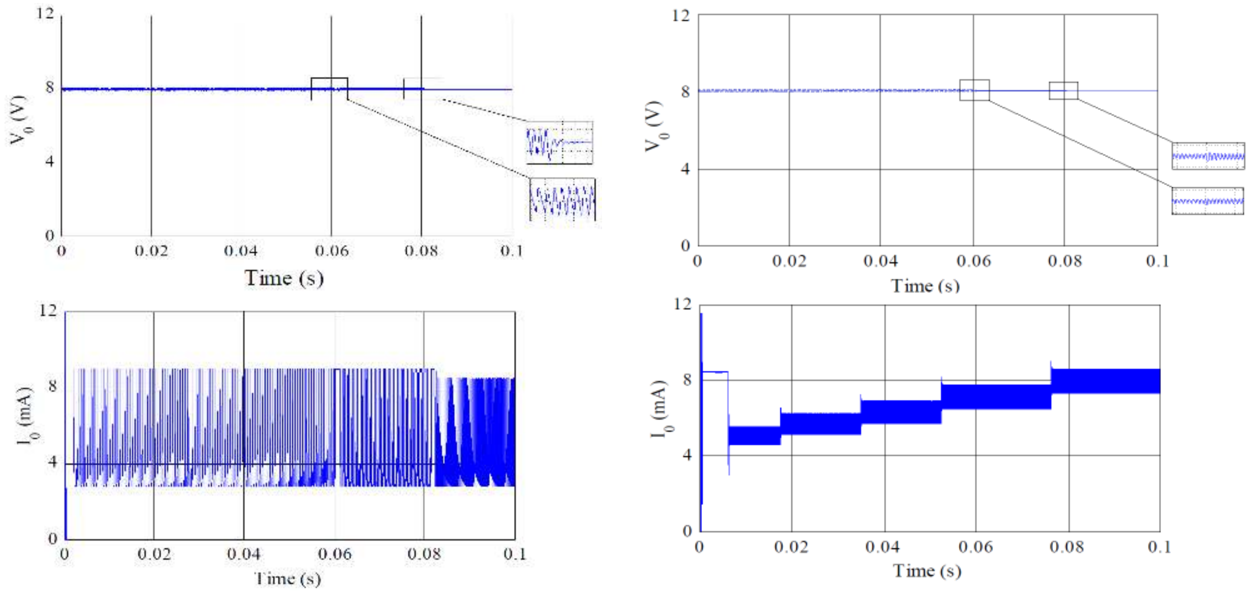


Figure 7. V_0, I_0 of the proposed controller in deviation at irradiation state



(a) (b)

Figure 8. V_0 and I_0 for Load Disturbance conditions (a) ANFIS (b) PSO-DFFP in 60mSec & 80Sec.

Table 3. Static and dynamic Performance

Controllers	Rise time in Sec	Steady state error	t_s in mSec.	THD	% Peak Over shoot
FLC (Umadevi and Nagarajan, 2020)	0.78	0.04	1.5	11.2	0
ANFIS (Umadevi and Nagarajan, 2020)	0.59	0.001	0. 9	6.8	0
PSO-DFFP	0.4	0.0001	0. 6	5.2	0

t_{s-} Settling Time

Table 4. Controllers' performance in Line Disturbance

Controllers	Line Disturbance with rated supply					
	25%		50%		100%	
	t_s in mSec.	% peak over Shoot	t_s in mSec.	% peak over Shoot	t_s in mSec.	% peak over Shoot
FLC (Umadevi and Nagarajan, 2020)	35	0.37	38	0.4	40	0.31
ANFIS (Umadevi and Nagarajan, 2020)	12	0.0001	16	0.0001	17	0.0001
PSO-DFFP	10	0.00001	15	0.00001	16	0.00001

The static and overall dynamic performances of the two controllers are tabulated table 3. It is absorbed from the table 3 the developed PSO DFFP system give faster falling time with zero % peak overshoot contrasted with ANFIS controllers.

Table 5. Controllers' performance in Load Disturbance

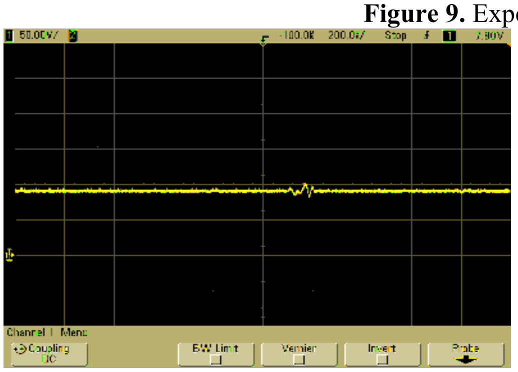
Controllers	**Load Disturbance with rated Load**					
	25%		**50%**		**100%**	
	t_s in mSec.	**% peak over Shoot**	**t_s in mSec.**	**% peak over Shoot**	**t_s in mSec.**	**% peak over Shoot**
FLC (Umadevi and Nagarajan, 2020)	30	0.036	32	0.026	33	0.035
ANFIS (Umadevi and Nagarajan, 2020)	15	0.0001	18	0.0001	19	0.0001
PSO-DFFP	14	0.00001	17	0.00001	18	0.00001

The controller performance is analyzed with Line and Load interruption at 0.06 sec and 0.08sec respectively and it's tabulated at table 4 and 5. It is shown that the PSO DEEP system performed well in all load changing and interruption conditions. The designed PSO DFFP system given the superior % peak overshoot and quick dynamic response compared with ANFIS system. The developed PSO DFFP system produced the % peak overshoot is nearly zero and 18msec of the timing to settled at the 100% load state. The simulation results are proved that the proposed system is better compared with ANFIS. It is concluded that the % peak overshoot and t_s are less with fewer oscillations compared with ANFIS controller.

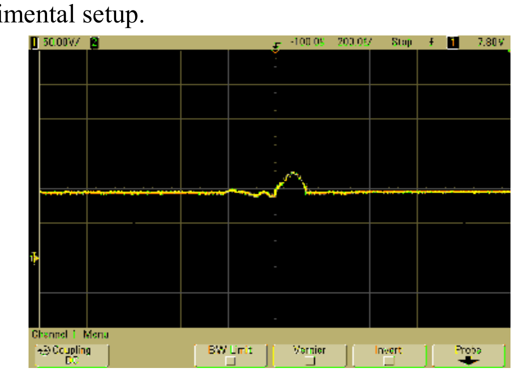
3.4 Experimental Setup:

The solar panel based boost DC to DC converter with NICI system is demonstrated and performance is analyzed. The PSO-DFFP system is operated with 200W, 100kHz is designed and presented. The P89V51RD2BN modern microcontroller is produced the PWM signals for the switches and the converter operating switches as used in IRFP940 MOSFET. The freewheeling diodes are MUR4100 and the microcontroller are produced the 100kHz operating frequency. The driving pulse width modulation signals are received from the P89V51RD2BN and CYN 19-1 (opt coupler). The output voltage can be possessed from the PSO DFFP controller output. The output voltages of the converter are calculated by with GP1L53V. P89V51RD2BN controller received the feedback signal from ADC IC (ADC0808CCNB) and an ALM2907 driver is used to give the pluses. The model of the converter with solar panel are shown in fig.9

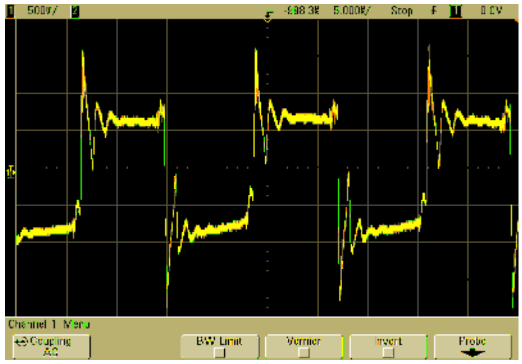
Figure 9. Experimental setup.



(a)

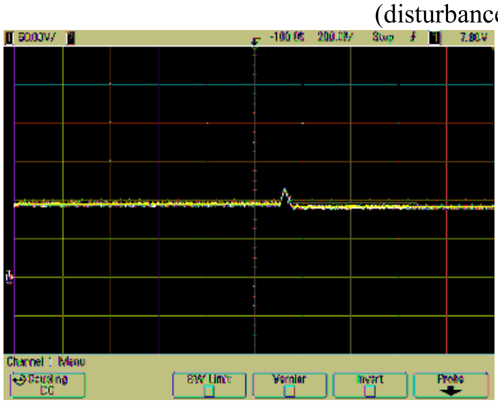


(b)

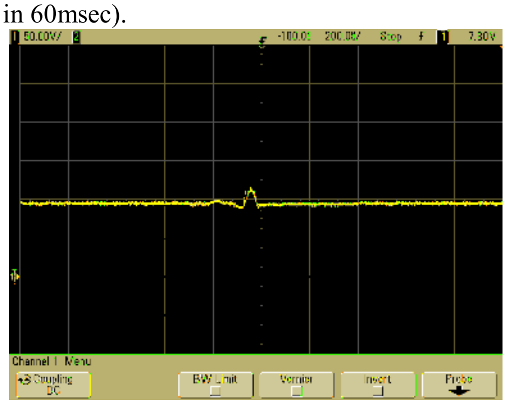


(c)

Figure 10. V_0 and I_0 using ANFIS controller (a) in Line disturbance (b) in Load disturbance (c) I_0 in 100% load interruption (disturbance in 60msec).



(a)



(b)

(c)

Figure 11. V_0 and I_0 using PSO DEEP controller (a) in Line disturbance (b) in Load disturbance (c) I_0 in 100% load interruption (disturbance in 60msec).

The V_0 (output voltage) and I_0 (output current) of the converter operated with ANFIS and PSO DEEP controllers are presented in fig 10 and 11. The fig 10 and 11 shows the converter operated in 100 percentage load disturbance and line interruption in 60msec. It is absorbed from the fig 11, the PSO DEEP controller performs well in transient and dynamic conditions compared with ANFIS converters. The ANFIS controller produces more fluctuation and high percentage peak overshoot in 100% load interruption condition. The experimental results of the ANFIS and PSO DEEP controllers are presented in table 6. It is concluded from the tabulated results the proposed PSO DEEP controller gives a smaller amount oscillation under operated in line interruption and load interruption conditions.

Table 6. Investigational analysis

Controllers	**t_s in mSec.**	**Steady state error**	**Rise time in Sec**	**% Peak Overshoot**
FLC (Umadevi and Nagarajan, 2020)	189	0.62	1.3	1.68
ANFIS	80	0.12	0.89	0.9
PSO-DFFP	60	0.1	0.72	0.84

$t_{s\text{-}}$ Settling Time

3. Conclusion

The developed PSO DFFP controller can be compared with ANFIS and fuzzy logic controller and estimated with simulink/ MATLAB tool are presented. The mathematical analysis of the DC to DC boost converter is designed and the converter is simulated using MATLAB simulation. The controllers are evaluated with 100% load interruption and rated supply line interruption conditions. The static and dynamic performance of the controllers are evaluated and compared. The Investigational analysis of the proposed system was presented with performance analysis comparison. It is concluded that the PSO DEEP controller produced better static and dynamic appearance. The converter is designed with 200W, 100 kHz operating frequency and it was demonstrated. The Investigational results are closely materialized with the simulations results.

References

Adib E., Farzanehfard H., 2019, Soft switching bidirectional DC-DC converter for ultra capacitor batteries interface, *Energy Conversion and Management*, Vol. 50, No. 12, pp. 2879-2884. https://doi.org/10.1016/j.enconman.2009.07.001

Baggio J.E., Hey H.L., Grundling H.A., Pinheiro H., Pinheiro J.R., 2018, Isolated interleaved phase shift PWM DC-DC ZVS converter, IEEE *Transactions on Industry Applications,* Vol. 39, No. 6, pp.1795-1802. https://doi.org/10.1109/TIA.2003.818965

Balestrino A., Landi A., Sani L., 2002, Cuk converter global control via fuzzy logic and scaling factors, *IEEE Transactions on Industry Applications,* Vol. 38, No. 2, pp. 406-413. https://doi.org/10.1109/28.993162

Banu J.B., Moses M.B., 2016, Soft switching bidirectional buck boost converter with simple auxiliary circuit, *Indian Journal of Science and Technology*, Vol. 9, No. 48, pp. 1-10. https://doi.org/10.17485/ijst/2016/v9i48/98037

Bei T., Wang P., Yang L., and Zhou Z., 2014, Dynamic sliding mode evolution PWM controller for a novel high-gain interleaved DC-DC converter in PV system, *Journal of Applied Mathematics*, Vol. 2014, Article ID 658674, pp.1-11. https://doi.org/10.1155/2014/658674

Cheng K.-H., Hsu C.F., Lin C.-M., Lee T.-T., Li C., 2007, Fuzzy neural sliding mode control for DC-DC converters using asymmetric Gaussian membership functions, *IEEE Transactions on Industrial Electronics*, Vol. 54, No. 3, 2017, pp. 1528-1536. https://doi.org/10.1109/TIE.2007.894717

Farahani H.F., 2007, Designing and implementation of a fuzzy controller for DC-DC converters and comparing with PI digital controller, *Australian Journal of Basic and Applied Sciences*, Vol. 5, No. 7, pp. 276-285.

Gu B., Dominic J., Lai J.-S., Zhao Z., and Liu C., 2013, High boost ratio hybrid transformer DC-DC converter for photovoltaic module applications, *IEEE Transactions on Power Electronics*, Vol. 28, No. 4, pp. 2048-2058. https://doi.org/10.1109/TPEL.2012.2198834

Kumar S.S. and Nagarajan C., 2016, Performance - economic and energy loss analysis of 80 kWp grid connected roof top transformer less photovoltaic power plant, *Circuits and Systems Journal, Scientific Research Publication*, Vol. 7, No. 6, pp. 662-679. https://doi.org/10.4236/cs.2016.76056

Lakshmi C.S., Nagarajan C., 2021, Comparison of shunt active filter controllers for harmonic elimination, *Suraj Punj Journal for Multidisciplinary Research*, Vol. 11, No. 4, pp. 674- 678.

Liu D., Li H., 2006, A ZVS bi-directional DC-DC converter for multiple energy storage elements, *IEEE Transactions on Power Electronics,* Vol. 21, No. 5,pp. 1513-1517. https://doi.org/10.1109/TPEL.2006.882450

Prasad J.S., Obulesh Y.P., Babu C.S., 2016, FPGA (field programmable gate array) controlled solar based zero voltage and zero current switching DC-DC converter for battery storage applications, *Energy*, Vol. 106, pp. 728-742. https://doi.org/10.1016/j.energy.2016.03.002

Nagarajan C. and Madheswaran M., 2011a, Stability analysis of series parallel resonant converter with fuzzy logic controller using state space techniques, *Electric Power Components and Systems*, vol. 39, no. 8, pp.780-793, https://doi.org/10.1080/15325008.2010.541746.

Nagarajan C. and Madheswaran M., 2011b, Performance analysis of LCL-T resonant converter with fuzzy/PID using state space analysis *Springer, Electrical Engineering*, Vol. 93, No. 3, pp.167-178. https://doi.org/10.1007/s00202-011-0203-9

Nagarajan C. and Madheswaran M., 2012a, Experimental verification and stability state space analysis of CLL-T series parallel resonant converter with fuzzy controller, *Journal of Electrical Engineering*, Vol. 63, No. 6, pp. 365-372. https://doi.org/10.2478/v10187-012-0054-2

Nagarajan C., Muruganandam M. and Ramasubramanian D., 2012, Analysis and design of CLL resonant converter for solar panel-battery systems, *International Journal of Intelligent systems and Applications,* Vol. 5, No. 1, pp. 52-58, 2012, https://doi.org/10.5815/ijisa. 2013.01.05.

Nagarajan C., Madheswaran M. and Ramasubramanian D., 2013, Development of DSP based robust control method for general resonant converter topologies using transfer function model, *Acta Electrotechnica et Informatica,* Vol.13, No. 2, pp.18-31.

Nagarajan C. and Madheswaran M., 2012b, DSP based fuzzy controller for series parallel resonant converter, *Frontiers of Electrical and Electronic Engineering*, Vol. 7, No. 4, pp. 438-446. https://doi.org/10.1007/s11460-012-0212-0

Nagarajan C. and Mathiyalagan C., 2012c, Design and implementation of bridgeless buck converter with fuzzy controller fed PMDC drive, *Journal on Soft Computing*, Vol. 2, No. 3, pp.337-340. https://doi.org/10.21917/ijsc.2012.0052

Nagarajan C., Tharani B., Saravanan S. and Prakash R., 2022a, Performance estimation and control analysis of AC-DC/DC-DC hybrid multi-port intelligent controllers based power flow optimizing using STEM strategy and RPFC technique, *International Journal of Robotics and Control Systems*, Vol. 2, No 1, pp-124-139. https://doi.org/10.31763/ijrcs.v2i1.562

Nagarajan C., Tharani B., Saravanan S. and Muruganandam M., 2021, Performance analysis of hybrid multi-Port AC-DC/DC-DC embedded based energy flow optimizing using resilient power flow control (RPFC) technique, *Asian Journal of Electrical Sciences,* Vol. 10, No. 2, pp. 16 -28.

Nagarajan C., Srinivasan R., Padmapriya B., Pradeepa A., Swathi M., 2022b, PSO-DFFP technique used for optimal network reconfiguration with dispersed generation, *Journal of Control & Instrumentation*, Vol. 13, No. 2, pp. 1-8.

Nagarajan C., Umadevi K., Saravanan S., Muruganandam M., 2022, Performance investigation on boost converter with non-isolated coupled inductor using PSO-DFFP controller with stand-alone PV System, *Journal of Control & Instrumentation*, Vol. 13, No. 1, pp. 32-51.

Nagarajan C., Vinoth D., Ajith M., Barath K. and Dinakaran V., 2022c, Particle swarm optimization technique used for optimal network reconfiguration with dispersed generation, *Asian Journal of Electrical Sciences*, Vol.11 No.1, pp.33-38

Stalin B., Sivakumaran T.S., 2016, Performance evaluation of bidirectional soft switching converter with implementation of PI and fuzzy logic controllers, *International Journal of Advanced Engineering Technology*, Vol. 7, No. 3, pp. 42-53

Tharani B., Nagarajan C., 2020, An AC–DC/DC–DC hybrid multi-port embedded energy router based Steady-state power flow optimizing in power system using substantial transformative energy management strategy, Springer, *Journal of Ambient Intelligence and Humanized Computing*, Vol.12,No 5, pp. 5687-5707. https://doi.org/10.1007/s12652-020-02362-8

Umadevi K., Nagarajan C., 2020, Design and implementation of novel soft switching method based DC-DC converter with non-isolated coupled inductor in solar system using FPGA, *Microprocessors and Microsystems* , Vol.73, 102952. https://doi.org/10.1016/j.micpro.2019.102952

Xiao H., Xie S., 2008, A ZVS bidirectional DC–DC converter with phase-shift plus PWM control scheme, *IEEE Transactions on Power Electronics*, Vol. 23, No. 2, pp. 813-823. https://doi.org/10.1109/TPEL.2007.915188

Zhang Z., Eberle W., 2009, A non isolated ZVS asymmetrical buck voltage regulator module with direct energy transfer, *IEEE Transactions on Industrial Electronics,* Vol. 56, No. 8, pp. 3096-3105. https://doi.org/10.1109/TIE.2009.2023102

Zhang J., Lai J.S., Kim R.Y., Yu W., 2007, High-power density design of a soft-switching high-power bidirectional DC-DC converter, *IEEE Transactions on Power Electronics*, Vol. 22, No. 4,pp. 1145-1153. https://doi.org/10.1109/TPEL.2007.900462

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