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A Novel M-SEPIC DC-DC Converter for BLDC Pumping System with Active PFC using ANFIS Controller

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ABSTRACT

An exigent consumer related concerns confronted due to utilization of massive front-end AC-DC rectifier in a grid-tied BLDC pumping system. Harmonic distortions are acquired, which prompts the disruption of power quality at utility grid system due to AC-DC conversion. Several factors for enhancing power-quality concerns are ameliorate the grid power-factor along with reduction of harmonic distortions, tightened regulation of DC output voltage. In this way, the DC-DC boost converter plays a unique role; operated in Continuous Conduction Mode. Based on summarizing advantages & disadvantages of classical DC-DC converters, a single switch high voltage gain M-SEPIC DC-DC converter is more suggestive for water pumping system due to non-existence of coupled inductors, low switching loss, low di/dt stress, high efficiency, compact structure, low cost, etc. This work proposes the novel M-SEPIC DC-DC converter fed brushless-DC motor drive is controlled by voltage source inverter and powered by single-phase grid system with improved power-quality features. Moreover, Adaptive Neuro-Fuzzy Inference System is recommended for prediction of optimal switching states to amplify the BLDC motor speed and torque-ripple depreciation. The effectiveness of the proposed scheme is validated under constant speed situations by real-time operating conditions which are evaluated by Matlab /Simulink tool; and simulation results are conferred with attractive comparisons.

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1. INTRODUCTION

Dispensing the clean water as surplus quantity, sustainable development and securing the good health are the prime issues for farmers in irrigation system, house-hold and commercial applications. Abundant water resource is the major requirement of farmers in irrigation system which is established by massive pumping system. Several challenges come-up with a simple, efficient, low-cost and reliable ways influencing the present research methodologies towards the utility grid fed water pumping system by using electric-drive technology. The power electronic technology is generally used for powering the electric drive from a AC single-phase source from the utility grid by utilizing the front-end Diode-Bridge Rectifier (DBR) accompained by capacitor filter. The DBR accompained filter unit provokes significant deteriotion of power quality features and violates the IEC-61000-3-2 standards [1]. Moreover, dominants the more harmonic current distortions at AC source with a high crest factor, extreme low power-factor, the AC mains current waveform is non-sinusoidal, high peaky and distorted component [2], [3]. Due to these concerns, enhanced power-quality based drive-technology is imperatively being proposed, which are presumed to extract a pure sinusoidal current with a incredible unity power-factor [4].

To achieve a perceivable enhancements in power-quality, power-factor correction (PFC) devices are recruited and placed at the utility grid system or common utility point [5], [6]. Power Factor Correction (PFC) devices are able to acquire low THD content in source current, unity PF, reliable operation, incredible efficiency, stiffy regulation of DC output voltage [7]. Several PFC techniques have been introduced and classified as two variants such as, passive and active techniques. Passive PFC technique consisted of passive elements like capacitor and inductor which are interfaced as input filter to minimize the source current harmonics, it is not significant relatively bulky size, doesn't handle the dynamic situations. An efficient active PFC methodology is comprised of passive components and switches, utilizes a DBR accompained by DC-DC converters. By regulating the DC-DC converter, the AC source current is super-intend to follow the source voltage to constituted as unity power factor. The general block diagram of proposed pumping system is depicted in Figure 1.

For high and medium power ranges, boost converter is more suitable becuase of low EMI and requires low filtering requirement due to continous line current. The energy coming from the utility grid is integrated to pumping system by utilizing power-conditiong apparatus [8], which plays a key role consisted of DC-DC converter and three phase Voltage Source Inverter (VSI) with attractive control schemes. Several high voltage gain DC-DC converters are reviewed, classical DC-DC converters are regular boost converter [9], buck-boost converter [10], switched capacitor type [11],[12], Cuk converter [13], SEPIC converter [14] etc. The SEPIC converter plays a significant role in water pumping system due to wide range of output gain in both step-down/step up conversion as well as it suffers from high dv/dt and di/dt stress, which increases the loss and minimize efficiency. These disadvantages are overcome by modified SEPIC topology named as M-SEPIC converter by accomplishing supplement capacitor and diode apparatus [15]-[18]. The merits of proposed M-SEPIC converter is high voltage gain, low EMI loss, low dv/dt and di/dt stress, incredible efficiency, reliable operation, compact size, low cost, etc.

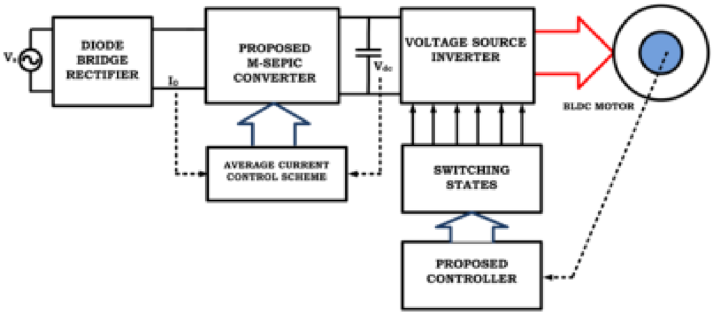


Figure 1. General Block Diagram of Proposed Pumping System

Coming to selection of electric motor in drive technology, DC motors have several disadvantages like more maintenance due to commutator and brushes, spark generation, high inertia, etc. The related issues with DC motor is discarded by employing induction motor, but it have low efficiency, induce the over-heating under very-low voltage conditions. Brushless DC (BLDC) motor is more popular owing to superb merits and desirable operational features for pumping application [19]. The imperative merits of BLDC motor over formal are more ruggedness, incredible efficiency, reliable operation, low EMI compatibility, high torque-weight ratio, low maintenance, simple control objective, generally working under low voltages as well as outstanding performance under wide speed ranges [20]-[22].

In this paper, a DBR followed high-voltage gain single switch M-SEPIC DC-DC converter fed BLDC drive is proposed by employing Adaptive Neuro-Fuzzy Inference System (ANFIS). The credability of ANFIS controller is mainly constituted for symbolic path along with competence knowledge for divination of optimum switching states to VSI. The vital resolution of ANFIS controller offers regulated speed responses under sudden deviations, diminishing the torque ripples over the classical PI, Fuzzy control schemes. Finally, the vigorous recognition of proposed pumping application under various PI and intelligent control schemes are validated under real-time working conditions with improved power-quality features which are manifested through Matlab/Simulink tool and results are conferred.

2. PROPOSED SYSTEM

The proposed DBR followed high-voltage gain single-switch M-SEPIC DC-DC converter fed BLDC drive for water pumping system is depicted in Figure 2. From left to right position, the proposed configuration consisting of single phase AC supply from utility grid, BDR followed M-SEPIC DC-DC converter, VSI fed BLDC drive system with asymmetric control objective. Asymmetric control objective have dual multi-loop techniques, such as ANFIS control scheme and mean current control methodology for generation of switching states to M-SEPIC converter. The proposed converter is working under Continous Conduction Mode (CCM) and Discontinous Conduction Mode (DCM) but, switch stress and switching devices are very low in CCM only. The importance of M-SEPIC converter transforms the energy from utility AC grid to BLDC motor drive via VSI topology with respect to minimize the obstacles coming from the AC-DC conversion while using DBR followed by filter units. The design, analysis of proposed DBR followed high-voltage single switch M-SEPIC converter fed BLDC drive with ANFIS control scheme is outlined as followed sections.

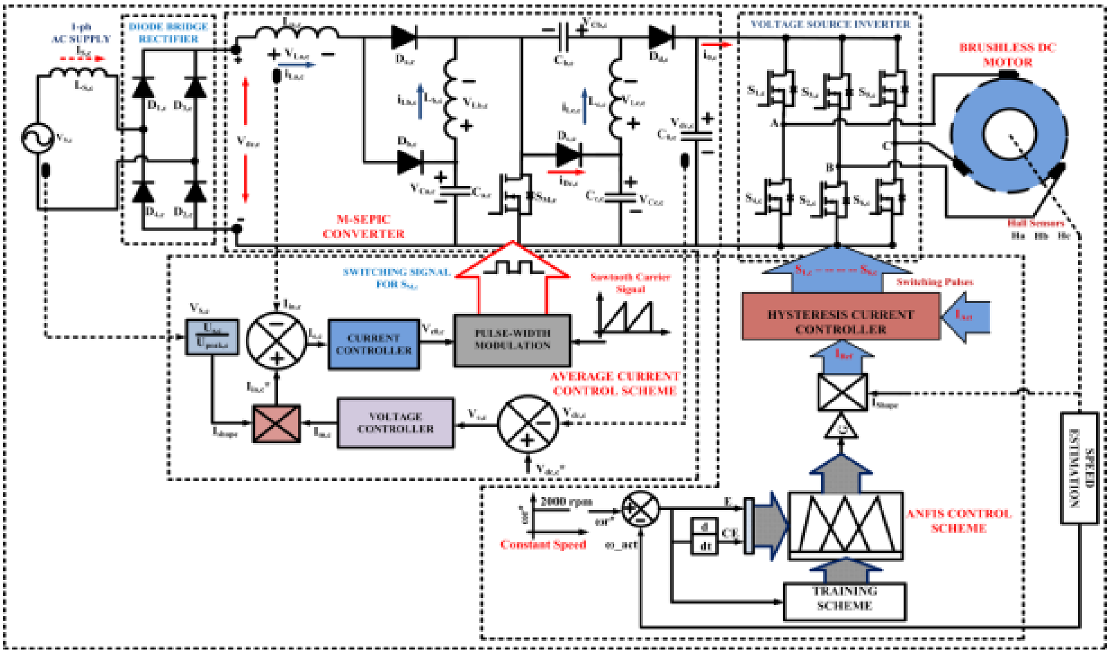


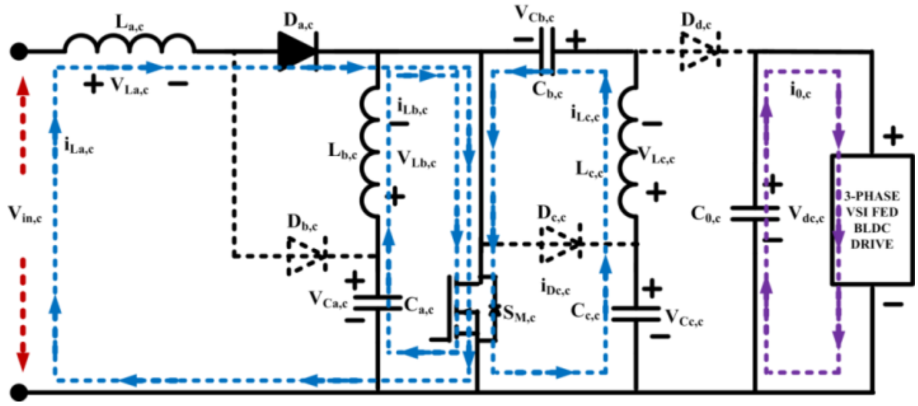
Figure 2. Schematic Diagram of Proposed Diode Bridge Rectfier Followed BLDC Drive Pumping System Employing M-SEPIC Converter

2.1 Proposed M-Sepic DC-DC Converter

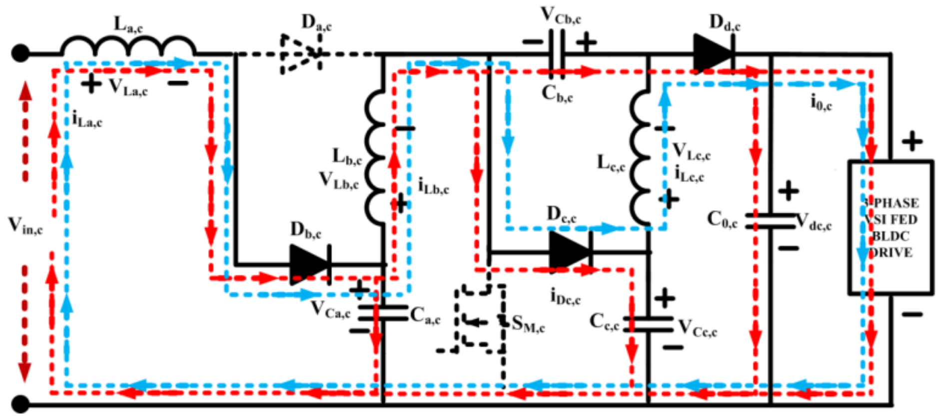
Single-switch high-voltage gain M-SEPIC converter is defined from a regular SEPIC module with accessory switching components, which transform the low-level DC voltage coming from BDR to high-level output voltage subjected to gain ratio. The accessory switching components are capacitor C_c, inductor L_b, diodes D_a, D_b are form as sub-multi module for getting more gain ratio. The clamping capacitor C_c and diode D_c acts as voltage clamping circuits of MOSFET switch S_M. Generally, the M-SEPIC converter is working under both CCM and DCM operating modes, when the inductor currents I_{La}, I_{Lb}, I_{Lc} are continous to flow then the converter is operated in a CCM mode. The working modes of M-SEPIC converter is shown in Figure 3 (a), (b). Selection of working modes of front-end DBR fed DC-DC converter depends on PFC switch stress and over-all system cost. The average current control technique offers low switch stress and sustain the DC-link voltage as constant [23]. Depending on evaluation, either technique may tend to force the DC-DC converter to work in CCM or DCM mode. In this way, A DBR followed M-SEPIC DC-DC converter fed BLDC drive is working in CCM operation as two operating modes which is investigated for wide-speed operation with unity PFC at AC utility mains.

Mode-II (t_1-t_2): When the time t=t_1-t_2, the switch $S_{M,c}$ and diode $D_{a,c}$ is switched-OFF due to discarding of switching pulses, the other diodes $D_{d,c}$, $D_{c,c}$, $D_{b,c}$ are conducted based on current direction, the current path for mode-II is described in Figure 3(b). The energy for this capacitor $C_{a,c}$ is supported by input supply voltage as $V_{in,c}$ and inductor $L_{a,c}$, the voltage across inductor $L_{a,c}$ is $V_{La,c}$ which is equal potential of

$V_{in,c}$ -$V_{Ca,c}$. On the other way, energy in capacitor $C_{c,c}$ is coming from input source voltage and respective inductors $L_{a,c}$, $L_{b,c}$, through diode $D_{b,c}$, then the voltage $V_{Lb,c}$ is equal potential of $V_{Ca,c}$ -$V_{Cc,c}$. Hence, obtain energy of $V_{in,c}$, $L_{a,c}$, $L_{b,c}$, and $L_{c,c}$ are transformed to $C_{0,c}$ and integrated to DC-link component and maintains DC-link voltage as constant, then the inductor currents $i_{La,c}$, $I_{Lb,c}$, $I_{Lc,c}$ decreased linearly with respect to $V_{Lc,c}$ is same as –$V_{Cb,c}$. When the time t=t_2, switch $S_{M,c}$ is switched-OFF, the M-SEPIC converter welcomes the next switching state.



3(a) Mode-I[t_0-t_1],



3(b) Mode-II [t_1-t_2]

Figure 3. Working Modes of Proposed Single-Switch M-SEPIC DC-DC Converter

The working modes-I and II are charcaterized by typical waveforms as depicted in Figure 4. Based on voltage-second balance principle of inductor is,

$$\left.\begin{aligned} DV_{in,c} &= (1-D)(V_{ca,c} - V_{in,c}) \\ DV_{Ca,c} &= (1-D)(V_{cc,c} - V_{ca,c}) \\ D(V_{cc,c} - V_{cb,c}) &= (1-D)(V_{cb,c}) \end{aligned}\right\} \tag{1}$$

Where 'D' represents the duty cycle of the switch $S_{M,c}$, imagine the capacitor voltage is sustained as constant under steady state condition, with the equivalence of Eqn.(1). The voltage across capacitor is defined as follows;

$$\left.\begin{aligned} V_{in,c} &= (1-D)\, V_{ca,c} \\ V_{Ca,c} &= (1-D)V_{cc,c} \\ V_{cb,c} &= DV_{cc,c} \end{aligned}\right\} \tag{2}$$

The output voltage $V_{dc,c}$ is same as the summation of capacitor voltages of $V_{Cc,c}$ and $V_{cb,c}$ during mode-II, the output gain ratio of the proposed M-SEPIC converter under CCM mode can be analysied by precribed duty cycle. The outcome gain ratio of proposed single-switch M-SEPIC converter is higher than the classical boost converters under non-isolated techniques.

$$M_{CCM} = \frac{V_{dc,c}}{V_{in,c}} = \frac{1+D}{(1-D)^2} \tag{3}$$

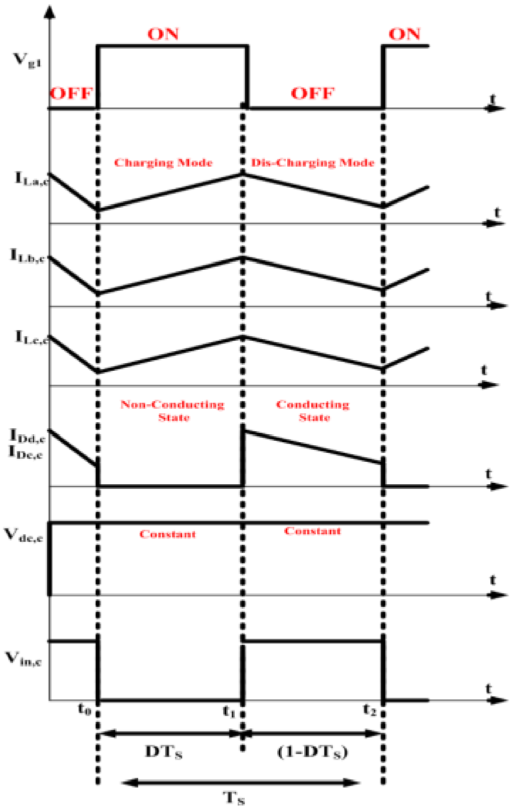


Figure 4. General Waveforms of M-SEPIC Converter Working Modes

2.1.1 Average Current Reference Control Technique for CCM Operation

An identical reference voltage (V_{dc}^{*}) is compared with actual DC-link voltage to produce the voltage error, the pertained voltage error at "k" instant is given as;

$$V_{e,c}(k) = V_{dc,c}^{*}(k) - V_{dc,c}(k) \tag{4}$$

The acquired voltage error is disposed by using proportional-integral (PI) voltage controller for reference current generation (I_m) as,

$$I_{m,c}(k) = V_{c,c}(k-1) + K_{pgv}\left(V_{e,c}(k) - V_{e,c}(k-1)\right) + K_{igv}V_{e,c}(k) \tag{5}$$

Where, K_{pgv} is proportional gain factor and K_{igv} is the integral gain factor of the PI voltage controller. The reference current shape (I_{shape}) is generated by unit-vector template of source voltage is multiplied to magnitude of reference outcome current to produce the absolute reference current ($I_{in,c}^{*}$) is,

$$I_{shape} = \left|\frac{U_{s,c}(k)}{U_{peak,c}}\right| s$$

$$I_{in,c}^{*}(k) = I_{shape} \times I_{m,c}(k) \tag{6}$$

This reference current component is compared to actual current to produce the error quantity given as;

$$i_{e,c}(k) = i^{*}_{in,c}(k) - i_{in,c}(k) \tag{7}$$

The outcome current error is given to the proportional-integral (PI) current controller to furnish the controlled output voltage ($V_{co,c}$) given as,

$$V_{co,c}(k) = V_{co,c}(k-1) + K_{pgi}\left(i_{e,c}(k) - i_{e,c}(k-1)\right) + K_{igi} i_{e,c}(k) \tag{8}$$

Where, K_{pgi} is proportional gain factor and K_{igi} is the integral gain factor of the PI current controller. Finally, the controlled output voltage $V_{co,c}(k)$ is conveyed to high switching frequency based sawtooth generator to produce the switching states to front-end DBR fed M-SEPIC converter switch as

$$m_d(t) < V_{co}(t)\ then\ S_{M,c} = 1; else\ S_{M,c} = 0 \tag{9}$$

Where $S_{M,c}$ represents the switching states as either 1 or 0 for MOSFET switch to switch ON/OFF, respectively.

2.2 BLDC Motor Drive System

A VSI configuration is needed to regulate the speed of the BLDC motor drive via Electronic Commutation (EC) process for optimal performance of pumping system. An EC circuit is required for sustaining the current flow in BLDC windings based on pre-requisite approach by employing the decode circuitry. It should be formed symmetrically at the input DC source current unit which is mid-point of every phase voltage for a displacement of 120º. Intiation of six-switching angles for feasible conjunction of three-hall sensors such as H_a, H_b, H_c, these states are provided by pre-defined encoder circuit which is tending to rotor position. An particular integrated scheme of hall sensing elements are produced by defined range of rotor-angles at interval of 60º, the six-switching sequences for estimation of rotor –position as illustrated in Table.1. It is more perceivable, because of dual switches are conducted at a time to form the 120º switching operation of VSI, which reduces the conduction losses. Although, the EC provides the fundamental switching frequency performance of VSI; for regulating the associated losses over the high switching frequency which eradicates the gate-drive circuits.

Table.1. Switching Pattern Selection Scheme of VSI Fed BLDC Drive for Irrigation Application

Switching Angles	Op. Seq	Hall Sensors			Switching Pattern						Phase Current Path		
		HA	HB	HC	$S1_{,c}$	$S2_{,c}$	$S3_{,c}$	$S4_{,c}$	$S5_{,c}$	$S6_{,c}$	A	B	C
0º~60º	A	1	0	0	1	0	0	0	0	1	+	-	off
60º~120º	B	1	1	0	1	1	0	0	0	0	+	off	-
120º~180º	C	0	1	0	0	1	1	0	0	0	off	+	-
180º~240º	D	0	1	1	0	0	1	1	0	0	-	+	off
240º~300º	E	0	0	1	0	0	0	1	1	0	-	off	+
300º~360º	F	1	0	1	0	0	0	0	1	1	off	-	+

2.3 ANFIS Control Scheme

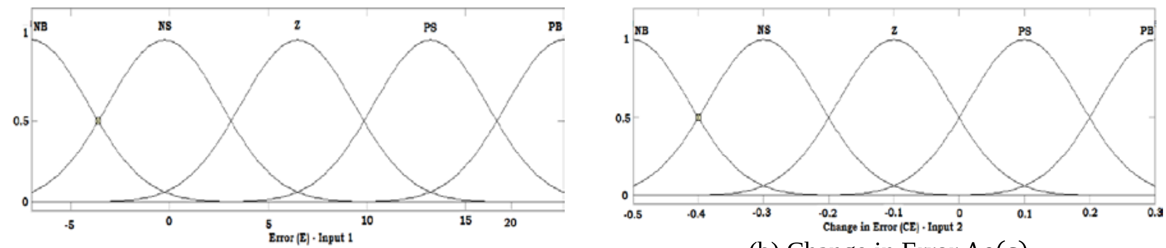
The switching states for VSI is furnished by current control objective along with electronic commutator for decoding the hall signals which accords to rotor position sensing and attractive control scheme. Generally PI controller plays a significant role in a VSI controlled BLDC drive system, the selection of gain parameters in PI controller is not a easy task. A Ziegler-Nichols tuning method is the best method for selection of optimal gain parameters to achieve the attractive performance. The classical PI acts as linear control objective, it is more efficient only for a restricted operating ranges under non-linear processes. On other side, intelligent controllers like Fuzzy controller plays a vital role in plant control processes which acts as non-linear controller. Fuzzy controller constituted as knowledge-based systems which involves Fuzzy membership functions and Fuzzy rules to integrate human knowledge in a knowldge base system. Some attempts have been established to attain an enhancement on system performance by integrated learning mechanisms to adjust the membership functions and/or rules of the Fuzzy-logic controller. Based on above discussion, an intelligent ANFIS controller is the optimal controller because of eminent characteristics, comprised as symbolic notation of inference system along with expertise knowledge [24].

Unique approach for respective task, which is predominantly regulate the motor speed and minimizng the torque ripples and yields the optimal switching sequences to the BLDC drive. It can enhance the over-all system performance as smooth, by reducing the torque ripples, maintain good stability index, good speed regulation, reliable operation, etc. In proposed ANFIS scheme, the knowledge base is furnished by supervised learning methodology by utilizing back-propagation or hybrid algorithm [25]-[30]. It is more reliable to achieve a favored group as an optimum membership functions which are merely recognized for deducting and clustering within a low epochs. At intial stage, a test fuzzy rules are transformed to affective training methodolgy for production of optimal membership functions and rules. If any violations are appeared and/or doesn't reaches the pre-requisite error value, a second stage is initaited and generates the new FIS configuration with respect to error quantities.

The memebrship functions for error (e) and change in error (ce) are depicted in Figure 5, these components are achieved by comparing the reference speed (ω_r^*) and actual speed (ω_{act}), these components are disposed by proposed ANFIS controller and produces the reference current magnitude. This reference current magnitude is multiplied with current shape (I_{shape}) and compared to actual currents for generation of optimal switching states to VSI fed BLDC drive system by using hysteresis current controller. These currents are controlled in between upper and lower limits of hysteresis band to regulate the switching states in VSI module. The pertained switching states are related to ON/OFF of the VSI switches which are highly demanded by reference current; when it is increased then switch is under ON state and decreased it should be in OFF state.

$$e(s) = \omega_r^* - \omega_{act} \quad (10)$$

$$\Delta e(s) = e(s) - e(s-1) \quad (11)$$



(a) Error e(s) (b) Change in Error $\Delta e(s)$

Figure 5. Membership Functions

Where, ω_r^* and ω_{act} denotes the reference and actual speed from speed estimator, e(s) and $\Delta e(s)$ denotes the error and change in error values. These outcome membership functions are named as Z-Zero, PS-Positive Small, PB-Positive Big and NS- Negative Small, NB-Negative Big, respectively and the rules of the proposed ANFIS structure is depicted in Table.2. the flow chart of ANFIS-Controller is depicted in Figure 6.

Table.2. Rules for ANFIS Structure

e(s) / $\Delta e(s)$	NB	NS	EZ	PS	PB
NB	MF-1	MF- 2	MF- 3	MF- 4	MF- 5
NS	MF- 6	MF- 7	MF- 8	MF- 9	MF- 10
Z	MF- 11	MF- 12	MF- 13	MF- 14	MF- 15
PS	MF- 16	MF- 17	MF- 18	MF- 19	MF- 20
PB	MF- 21	MF- 22	MF- 23	MF- 24	MF- 25

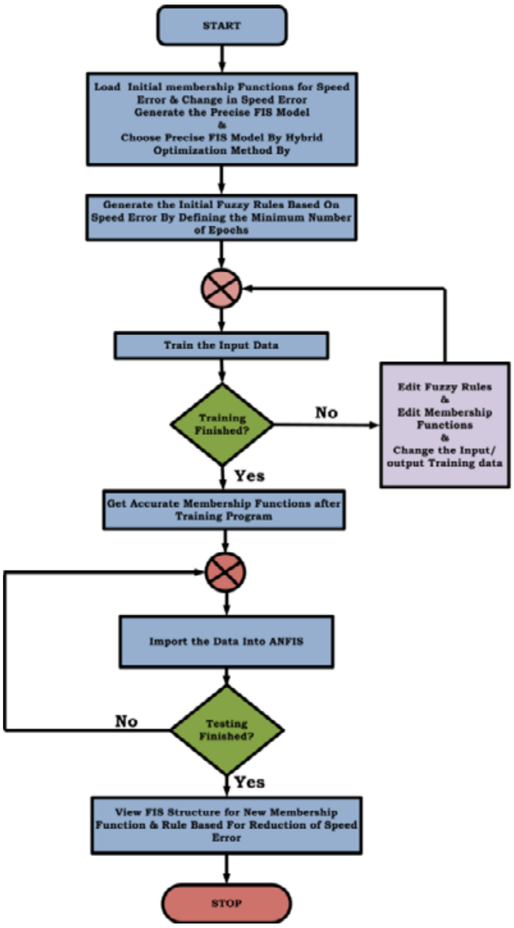


Figure 6. Flowchart of ANFIS Controller

3. MATLAB/SIMULATION RESULTS

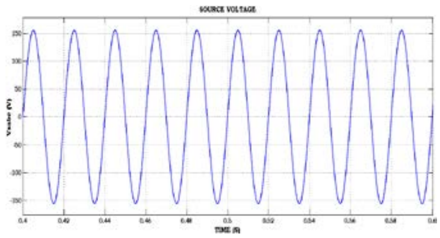
The performance of M-SEPIC DC-DC converter fed BLDC drive is simulated in CCM operation with constant speed situation by using Matlab/Simulink environment and is evaluated on the basis of several operating parameters, which are illustarted in Table 3.

Table 3. Operating Specifications

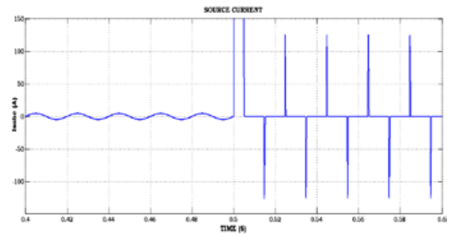
S.No	Parameters	Values
01	Grid Voltage & Frequency	V_g=230V, F_g =50Hz
02	Regulated Supply	V_s=110V, F_s =50Hz
03	Capacitive Filter	C_{dc} =10000 µF
04	DC-Link Voltage	520 V
05	Switching Frequency	100KHz
06	Inductors	L_a=127µH; L_b=550µH; L_c=295µH
07	Capacitors	C_a=C_0-470µF; C_b=C_c-2 µF
08	Rated Power of BLDC Motor	1 KW

3.1 Evaluation of Diode-Bridge Rectifier Followed with and without Capacitor Filter

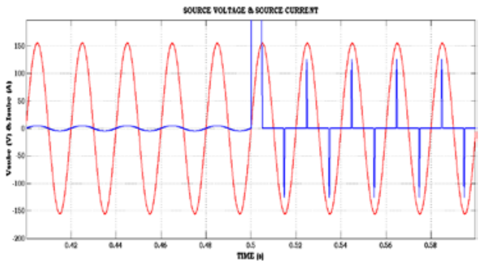
Figure 7 shows the simulation outcomes of DBR performance followed by with/without capacitor filter units with a simple R-load is connected. Generally, rectifier converts the AC to pulsating DC and this pulsating DC is tightened by filter units, while using filter the source utility paremeters goes to affected and violates the PQ features. In this case, a DBR is studided with and without capacitor filter which is operated at t=0.5 sec. The following parameters are (a) Source Voltage, (b) Source Current, (c) Source Voltage & Current, (d) Power Factor, (e) DC-Link Voltage, (f) THD Analysis of Source Current without Filter unit, (g) THD Analysis of Source Current out Filter unit. The source voltage is mainatained as sinusoidal with a operating frequency of 50Hz and the source current is distorted when the capacitive filter is switched ON, else current is also mainatined as sinusoidal and in-phase to specifiy the unity power factor (for clear vision the current value is multiplied by 10 times). The power factor of utility source is also affected when switch is ON, drops to 0.48 lags, else maintains unity power factor. Maintainng the DC-link voltage as constant when the capaitive filter is ON, other side pulstaing DC is getting and doesn't support pertain load charcateristics. The THD analysis of source current without filter is 0.7%, it should be in IEEE-512 standards and THD analysis of source current is 313.43% which is other than IEEE limits and affects the Power-Quality at utility grid when the capacitive filter is connected with DBR. A proper compensation technique is needed for enhancing the power-quality features and maintaing the DC-link voltage as constant.



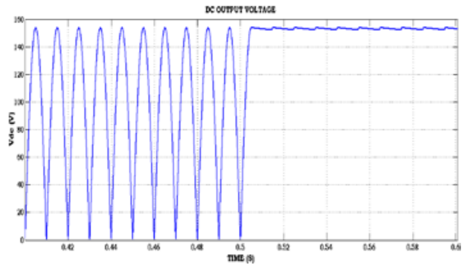
(a) Source Voltage



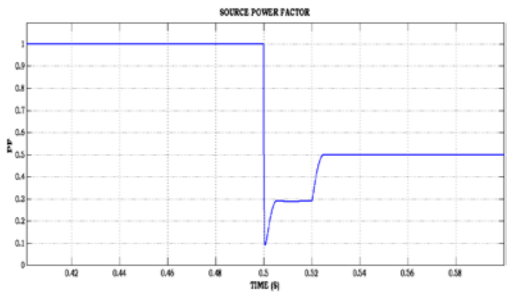
(b) Source Current



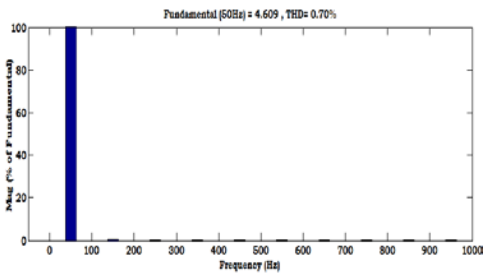
(c) Source Voltage & Current In Phase Condition



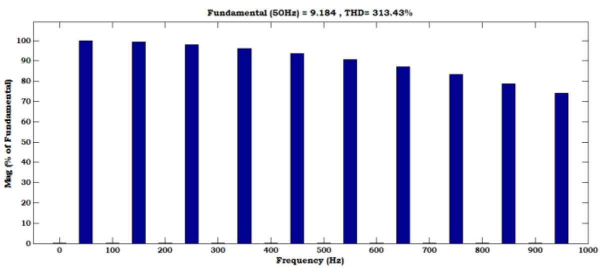
(d) DC-Link Voltage



(e) Power Factor



(f) THD of Source Current without Filter

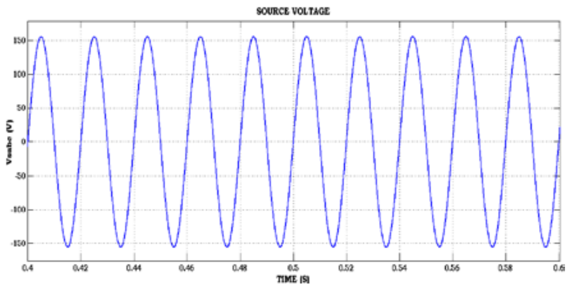


(g) THD of Source Current with Filter

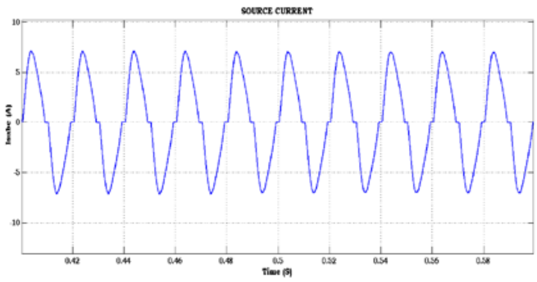
Figure 7 Performance of DBR followed with and without Capacitor Filter Unit

3.2 Evaluation of Diode-Bridge Rectifier Followed by Conventional DC-DC Boost Converter

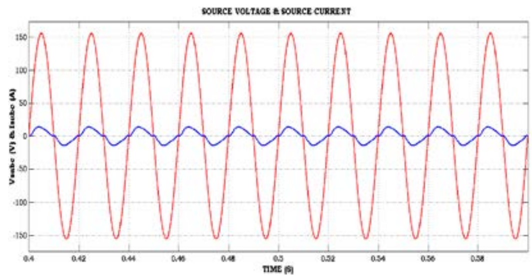
Figure 8 shows the simulation outcomes of DBR performance followed by Conventional DC-DC boost converter with a simple R-load is connected. Due to massive capacitor filter, source parameters goes to affected and violates the PQ features. An active PFC technique is intiatied over the passive technique, by utilizing DC-DC boost converter in place of capacitor filter which converts the low-voltage pulsating DC to high-voltage DC with tightened regulated output DC voltage as well as enhances the power-quality features at source AC side. The following parameters are (a) Source Voltage, (b) Source Current, (c) Source Voltage & Current, (d) Power Factor, (e) DC-Link Voltage, (f) THD Analysis of Source Current with Conventional DC-DC converter. The regulated source voltage is mainatained as sinusoidal with an operating frequency of 50Hz and the source current is maintained as sinusoidal and in-phase to specifiy the near unity power factor. The power factor of utility source is attained 0.78 lags, maintains nearly unity power factor. Maintainng the DC-link voltage as constant and getting boosted voltage which supports the pertained load charcateristics. The THD analysis of source current with conventionl DC-DC boost converter is 19.72%, value is very less when compared to DBR followed with capacitive filter.



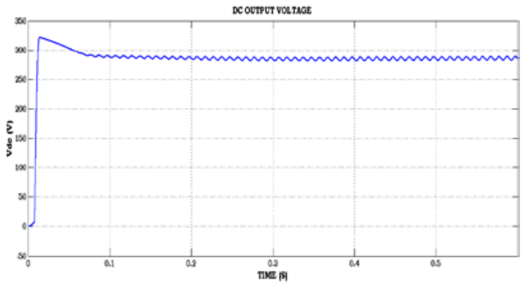
(a) Source Voltage



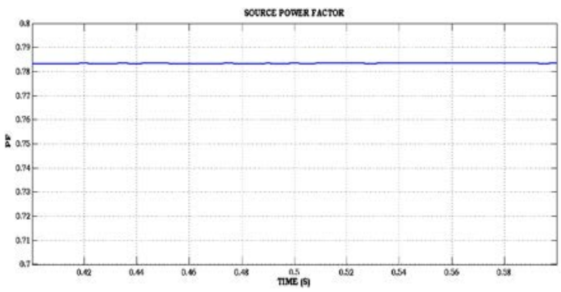
(b) Source Current



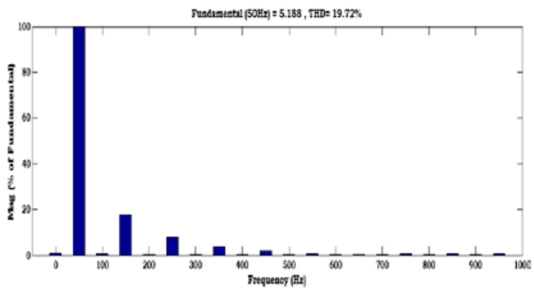
(c) Source Voltage & Current In Phase Condition



(d) DC-Link Voltage



(e) Power Factor

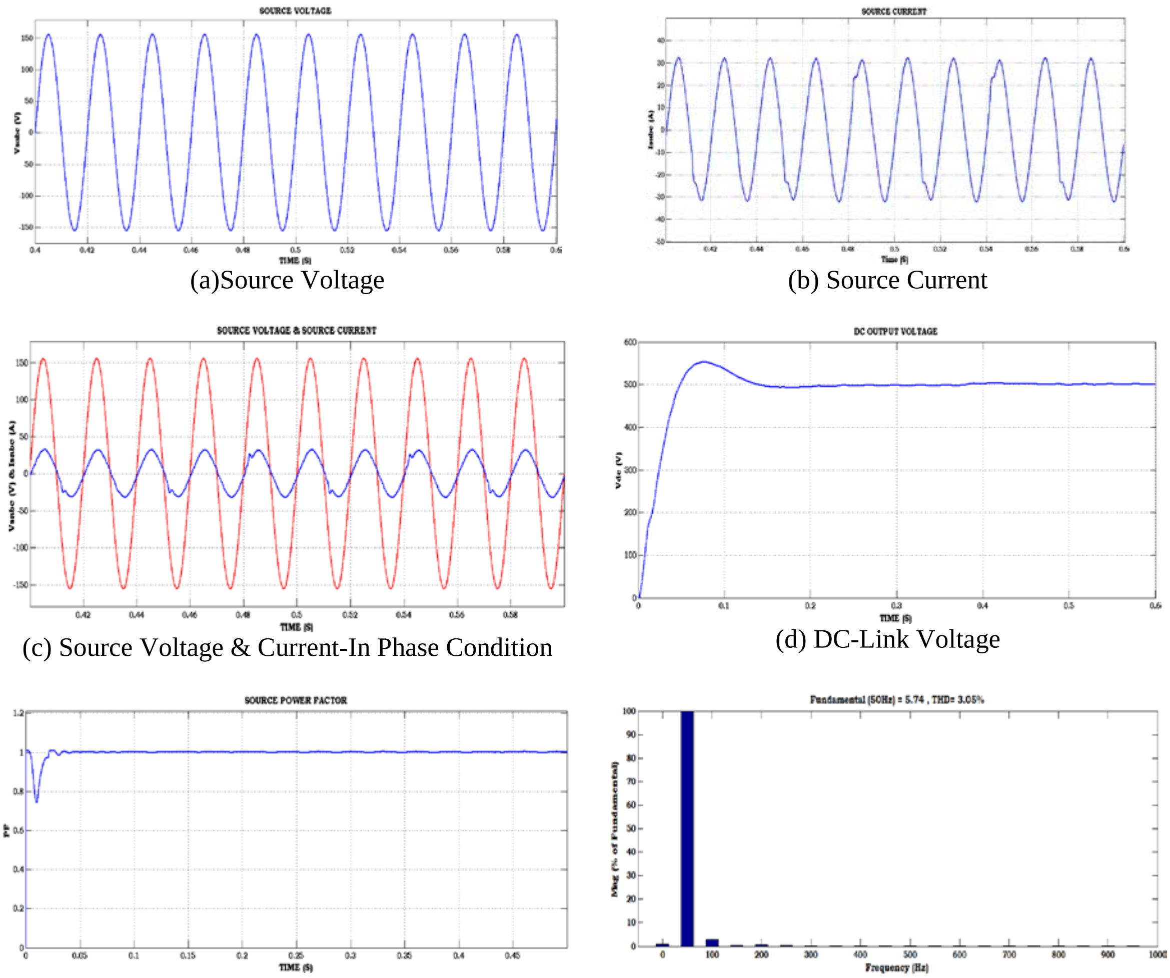


(f) THD of Source Current

Figure 8 Performance of DBR followed with Conventional DC-DC Boost Converter

3.3 Evaluation of Diode-Bridge Rectifier Followed by Proposed M-SEPIC DC-DC Converter

Figure 9 shows the simulation outcomes of DBR performance followed by Proposed M-SEPIC DC-DC converter with a BLDC Drive is connected. An active M-SEPIC converter is intiatied over the conventional technique, by utilizing M-SEPIC DC-DC converter in place of conventional, it has more advantages such as getting high voltage gain over the conventional, tightened output DC voltage regulation and enhanced power-quality features. The following parameters are (a) Source Voltage, (b) Source Current, (c) Source Voltage & Current, (d) Power Factor, (e) DC-Link Voltage, (f) THD Analysis of Source Current with Proposed M-SEPIC DC-DC converter. The regulated source voltage is mainatained as sinusoidal with an operating frequency of 50Hz and the source current is maintained as sinusoidal and in-phase to specifiy the near unity power factor (for clear vision the current value is multiplied by 5 times). The power factor of utility source is attained 0.999, maintains unity power factor. Maintainng the DC-link voltage as constant and getting boosted voltage more than conventional and supports the pertain load charcateristics. The THD analysis of source current with proposed M-SEPIC DC-DC converter is 3.05%, it is very less over the DBR followed with conventional DC-DC boost converter. It is well within IEEE-512 standards and enhances the power-quality features and achieves the BLDC drive system.



(a)Source Voltage (b) Source Current

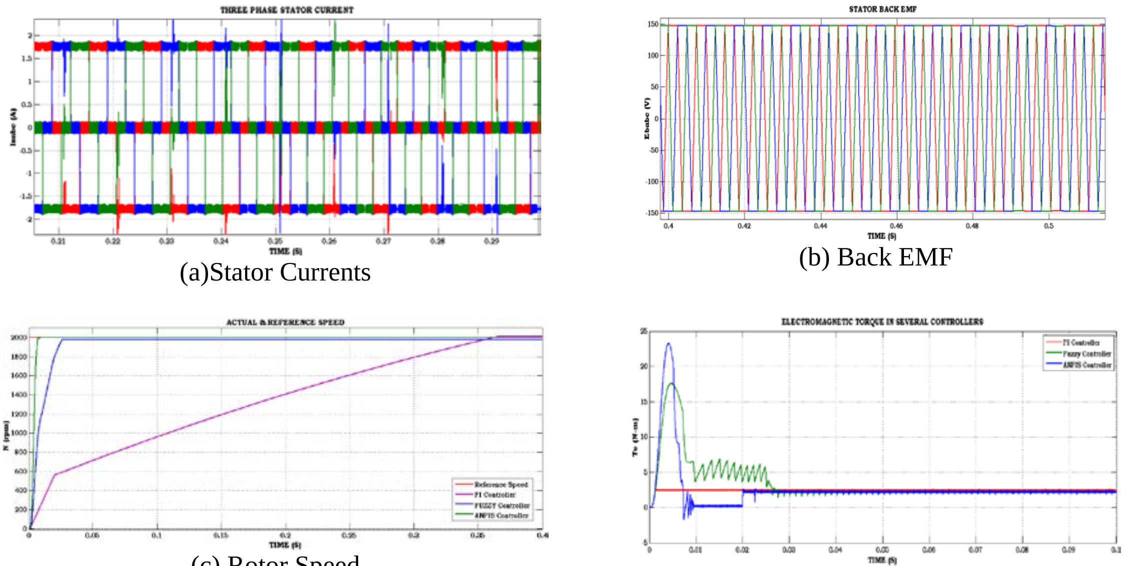
(c) Source Voltage & Current-In Phase Condition (d) DC-Link Voltage

(e) Power Factor (f) THD of Source Current

Figure9 Performance of DBR followed with Proposed M-SEPIC DC-DC Converter

3.4 Evaluation of Several Controllers in a proposed BLDC Driven under Constant Speed Condition.

Figure 10 shows the simulation outcomes of several controllers in a DBR followed Proposed M-SEPIC DC-DC converter under constant speed condition. In this condition, speed maintained as constant at 2000 rpm. The following parameters are llustrated, such as (a) Stator Currents, (b) Back Electro-Motive Force, (c) Rotor Speeds in PI, Fuzzy and ANFIS controllers, (d) Electro-magnetic Torque in PI, Fuzzy and ANFIS Controllers are analyzed. Under steady state condition, BLDC motor provides rated torque at specified speed condition and attains pulsated electro-magnetic torque due to electronic commutation process. The critical evaluation of BLDC drive with various controllers under constant speed condition, classical PI controller getting the rated speed at 0.365 sec, intelligent Fuzzy & ANFIS controllers getting rated speed at 0.03 sec and 0.0085 sec, respectively. Starting torque is predominantly high with a required Te of 20N-m, it was stabled in running conditions with a required Te of 2 N-m. The Back EMF and stator current is maintained as constant nearly 110 V and 1.8 A. By using several controllers to control the on-going current which minimizes the torque ripples, while using PI, Fuzzy, proposed ANFIS controllers torque ripples reduced to 8.88%, 10.24%, and 12.28%, as depicted in Figure 10. Proposed ANFIS controller have more advantages such as good stability index, reliable operation, reduction of speed error, minimization of torque ripples, etc., over classical PI, Fuzzy controllers. The THD analysis of source current is depicted in Table.4, without filter is 0.7%, it should be in IEEE-512 standards and THD analysis of source current is 313.43% when the capacitive filter is followed with DBR. The THD analysis of source current with conventionl DC-DC boost converter is 19.72%, while using proposed M-SEPIC DC-DC converter THD response is 3.05% it is well within IEEE-512 standards and enhances the power-quality features.



(a)Stator Currents (b) Back EMF

(c) Rotor Speed (d) Electro-Magnetic Torque

Figure 10 Performance of BLDC Drive under Constant Speed Condition by Several Controllers in a DBR Followed Proposed M-SEPIC DC-DC Converter

Table.4. THD Analysis of Source Current

THD (%)	Without Capacitor Filter	With Capacitor Filter	With Conventional DC-DC Converter	With Proposed M-SEPIC DC-DC Converter
Source Current	0.7%	313.43%	19.72%	3.05%

The critical evaluation of proposed DBR followed M-SEPIC DC-DC converter fed BLDC drive under constant situation by utilizing various control schemes are cleraly illustrated in Table.5. The attractive control schemes provide good stability index and minimizng the torque ripples by controlling the on-going and off-going currents of the BLDC drive via VSI. These current sequences operating the BLDC drive under the required speed conditions and achieves smooth operation in water pumping application. Various DC-DC converters are compared, the proposed M-SEPIC converter has more advantages and voltage gain factor also very high as illustrated in Table.6. The proposed DC-DC converter along with ANFIS controller furnishes the precise, error-free responses, better regulation of speed and reduced torque ripples, etc., are achieved and mostly suitable for water pumping system.

Table.5. Comparison of Settling Time & Torque Ripple Reduction in a BLDC Drive System Controlled by Several Controllers under Constant Speed Condition

Parameters	Under Constant Speed Situation (2000 rpm)	
	Settling Time of Speed	Torque Ripple Reduction
PI Controller	0.365 sec	8.96%
Fuzzy Controller	0.04 sec	10.32%
ANFIS Controller	0.0073 sec	12.56%

Table.6. Comparison of Several DC-DC Converters

S.No	Converter Type	Voltage Gain Factor
01	Conventional Boost Converter [9]	2%
02	Novel DC-DC Converter [27]	3%
03	Switched Capacitor [11]	4%
04	Switched Inductor [12]	4%
05	Proposed M-SEPIC Converter	5% to 8%

4. CONCLUSION

The grid integrated BLDC driven pumping system is more characterized by employing high-voltage gain M-SEPIC DC-DC converter with classical PI, Fuzzy and proposed ANFIS controllers. The critical evaluation of proposed work has been encouraged based on good operating statistics in constant speed situation by utilizing ANFIS controller. The proposed M-SEPIC converter acquires high voltage gain over the conventional DC-DC converters with non-presence of any couple inductors and requires single-switch device, provides the low switch stress, incredible efficiency, etc. To minimize the torque ripples, decreased speed error, improving the stability index, enhancing the power-quality features under various speed situations, are evaluated by using Matlab/Simulink environment. These combined advantages are more suitable for pumping application and economically very perfect. Achieving the enhanced power-quality features such as, improving the source side power-factor, harmonic reduction, tightened regulation of DC outcome voltage, are eminent provocations for maintaining the IEEE standards with greater reliability at decent consequences.

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