RFLSA CONTROL SCHEME FOR POWER QUALITY DISTURBANCES MITIGATION IN DSTATCOM WITH N-LEVEL INVERTER CONNECTED POWER SYSTEMS

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Abstract: *In this paper, a hybrid control scheme is proposed for the control of DSTATCOM's reactive power with phase shift modulation of n-level inverter power system. The article presents the hybrid technique of DSTATCOM which trials to mitigate the power quality complications of a power system. Here, the gain parameters of the PI controller are attuned to provide the optimal control signal of the n-level inverter based DSTATCOM. The optimal control signal has been determined utilizing random forest search algorithm (RFSA). Based on the minimum error function, the learning process of RFSA is enhanced by using the lightning search algorithm (LSA) and hence it is named as RFLSA technique. Then, the proposed technique is implemented in the MATLAB/Simulink platform and the performance is evaluated. The behavior of the proposed technique has been successfully compared with various techniques. Simulation results shows that the proposed technique has the capability of ensuring satisfactory dynamic response resulting high efficiency and diminished harmonics.*

Keywords: *Power quality, power system, n-level inverter, phase shift modulation, gain parameters, LSA and RFSA.*

1. Introduction

The power utilizations have expanded because of the expanded utilization of sensitive electronic components, PCs, programmable logic controllers, security and relaying equipments because of significant changes in a business domain. Electrical power systems are relied upon to convey power supply ceaselessly at high quality to the customers [1] because of expanding customer desires with the requirement of green supply the world over. The economy of any nation endures with enormous misfortunes when there are voltage or current variations present in the power delivery. Failure or missing of operation of client supplies [2] because of any deviation/disturbances showed in the voltage, current and frequency from the standard rating is treated as a power quality (PQ). In extensive quantities of energy sources, transmission lines, transformers and loads [3] show in the interconnected power networks, expanding sources of disturbances happen continually which causes PQ issues fundamentally. Exposures to natural disturbances like lightning strikes are notwithstanding such systems. System hardware breakdown; PC data loss and memory malfunction of sensitive loads, for example, PC, programmable logic controller controls, security and relaying equipment and erratic operation of electronic controls are caused because of PQ issues. To guarantee higher level of quality supply, for example, Uninterrupted power supply (UPS) and stabilizers and to keep these issues, clients will invest in on-site equipments despite the fact that these are expensive [1, 4]. Towards economic distribution of the energy the significance of power quality is appeared.

Issues, for example, harmonics, flicker, voltage dip/swell, voltage regulation, load unbalancing and deviations in phase as well as frequency [5-8] are misrepresented because of sustainable energy integration and smart transmission systems, well furnished with current control supplies, increment the utilizations of nonlinear and electronically switched devices in distribution systems. With the objective of enhancing supplied power quality in most recent two decades [9, 10] a few solid state electronic/power-electronic devices have been created, contemplated and proposed to the global academic group. As needs be, the reliability and quality of power that is conveyed to clients is upgraded by the FACTS based power electronic controllers for distribution systems, specifically custom power devices. Probably the most cost effective solutions for these sorts of power quality issues [11, 12] are in many occurrences, the utilization of a Distribution Level Static Compensator (D-STATCOM).

Normally supported by short-time energy stored in the dc link capacitor, D-STATCOM is a voltage source converter (VSC) based device. In the distribution network [13-15], it can adjust for reactive power, load unbalancing, voltage varieties and current harmonics. Utilized for estimation of reference currents, the execution of the DSTATCOM relies upon estimation of active and reactive powers, harmonic currents, and control algorithm. To upgrade the power quality [18, 19] the control strategies of DSTATCOM like Instantaneous power theory [16], synchronous reference frame theory (SRF), modified synchronous reference frame theory (MSRF), instantaneous symmetrical control theory [17] and average unit power factor theory (AUPF) have been produced. The quality of power systems [20] might be influenced by those strategies that unavoidably exist the issues of over or under compensation. Here, a combined execution of random forest search algorithm and lightning search algorithm (RFLSA) technique for D-STATCOM with n-level inverter is utilized. Plainly described in detail is the proposed technique. Talked about in section 2 is the remainder of this article, the recent research work and the background of the research work which is organized as follows. In section 3 and 4 thorough explanation of the proposed technique is explained. In section 5, the suggested technique achievement results and the related discussions are given and section 6 concludes the paper.

2. Recent Research Works and Problem Formulation

Several research works have previously existed in literature in literatures which are based on the power quality enhancement of D-STATCOM using various techniques and various aspects. Some of the works are reviewed here.

E. Lei *et al.* [21] have presented a novel integrated structure for a cascaded distribution static compensator (D-STATCOM) and distribution transformer for medium-voltage reactive power compensation. The three-phase winding taps were symmetrically arranged and the connection point voltage can be decreased to half of the line-to-line voltage at most. Thus, the voltage stress for the D-STATCOM was reduced and a compromise between the voltage rating and the current rating could be achieved. The spare capacity of the distribution transformer could also be fully used. The working mechanism was explained and a modified control strategy was proposed for reactive power compensation. N. VisaliKamarthi *et al.* [22] have discussed about the most important discussing topic in the world of power systems was maintenance of power quality. After generating voltage, the engineers in the substations were struggling for transmitting as well as distributing of power to the receiving end, since different loads at the ends of distribution were very sensitive to the fluctuations in the voltage, interruptions of voltage and harmonics. The improvement of Voltage Sag and THD using LCL Passive Filter along with the Distribution Static Compensator (D-STATCOM) which works with the principle of Voltage Source Converter (VSC).

These days, the usage of sensitive electronic equipment has expanded which has prompt to PQ issues. The different PQ disturbances are listed as follows transients, interruptions, voltage sag, voltage swell, voltage collapse, harmonics etc. To deal with these PQ issues distinctive custom power devices are used. DSTATCOM is a custom power device used for the utilized of voltage sag, swell and harmonics. The DSTATCOM is fast, versatile and effective solution for unravel the above issues. The DSTATCOM is intended for securing the whole plant with loads in the scope of some MVA. The DSTATCOM can reestablish the heap voltage inside couple of milliseconds. In addition, with the ideal voltage injection angle in view of least energy compensation, the target voltage function on which gives the appropriate compensation output voltage of DSTATCOM is resolved. The compensation performance of the DSTATCOM that much depends on upon it control algorithm. The control algorithms like artificial neural network (ANN), fuzzy logic control (FLC) differential evolutionary (DE) algorithm, simulated annealing (SA) and so forth, are utilized together with the ideal balance of the voltage droop to vanquish the voltage sag/swell issue. The ANN and FLC are working in based on the training data, so it can't give the proficient dynamic response and set aside more opportunity to execute or settle on the choice tenets. The DE and SA operation depends on arbitrary in nature thusly it causes infeasible arrangement with unnecessary computational time. A several configurations and control strategies are used for the DSTATCOM; however in the control algorithm requires an assistant support for finding out swell/sag/harmonic issue in system voltages to build up DSTATCOM performance. Consequently, an upgraded approach is expected to improve the DSTATCOM performance to alleviate the PQ issues in distribution system. In literature most of the works are presented to take care of this issue and the exhibited works are not giving the proficient outcomes. These issues and disadvantages have inspired to do this research work.

3. Proposed Control Structure of D-STATCOM

In power distribution network, DSTATCOM is associated in parallel at the purpose of common coupling which can regulate the system voltage by intriguing or generating the reactive power. Also, the DSTATCOM can also be utilized to enhance the stability of the power system by mitigating the power quality disturbances. The proposed control structure of the DSTATCOM installed at the mid-point of the transmission line is appeared in fig. 1.

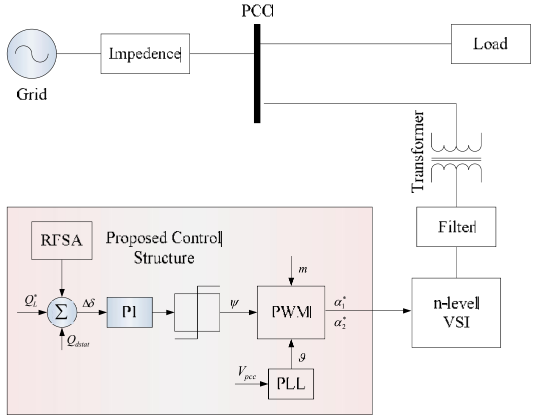


Fig. 1 Proposed control Scheme of DSTATCOM

The block diagram comprehends of a multilevel inverter associated to the distribution network by means of a coupling transformer. When the DSTATCOM is operated with a variable magnitude and phase angle, it can act as a synchronous voltage source. Accordingly, it is capable of controlling and rectifying its bus voltage and power factor respectively.

On considering the control strategy, the switch alternating can assimilate or engender the current depending upon the voltage of common coupling bus. From an energy storage capacitor, the voltage source converter engenders the output voltage of the DSTATCOM. Through the tie reactance, each output voltage is in phase with and coupled to the coterminous AC voltage. When the magnitude of the engendered output voltage gets diverse, the reactive power altercation is controlled between the DSTATCOM and AC system. Hence, the converter engenders or assimilates the reactive power if the amplitude of the output voltage is erected or detruded. Due to this reason, the DSTATCOM act as a shunt compensator which can infuse an opposite remuneration current.

Assume, at the middle of the transmission line the DSTATCOM is connected which connects the generator to the network. Excluding the generators and the DSTATCOM, the network equation is affirmed as,

$$I_{bus} = Y_{bus} \times V_{bus} \tag{1}$$

Where, the infused current is delineated as I_{bus}, the power system node voltage is represented as V_{bus} and the admittance matrix is represented as Y_{bus}. The capacitor voltage equation of the DSTATCOM is affirmed as,

$$\frac{dV_{dc}}{dt} = \frac{m}{C_{dc}}\left(I_{l0}^{d} Cos\phi + I_{lo}^{q} Sin\phi\right) \tag{2}$$

Where, V_{dc} represents the inverter dc voltage, C_{dc} is the storage capacitor, m is the modulation index of the pulse width. I_{l0}^{d} and I_{l0}^{q} symbolizes the reference current value for d and q axis and ϕ symbolizes the phase angle of the shunt inverter voltage.

3.1. Modeling

The single phase equivalent circuit model of the shunt connected VSC and its phasor diagram is exhibited in fig. 2. The internal resistance of the coupling transformer and the internal resistance of the input filter reactors form the total series resistance R. Also, the leakage reactance of the coupling transformer and reactance of input filter reactors forms the total series reactance X. When R<<X, the converter side power flow at can be transcribed as [23],

$$P_{dstat} \cong \frac{E_s V_{dstat}}{X} Sin(\psi) \tag{3}$$

$$Q_{dstat} \cong \frac{E_s V_{dstat}}{X}\left[E_s - V_{dstat} Cos(\psi)\right] \tag{4}$$

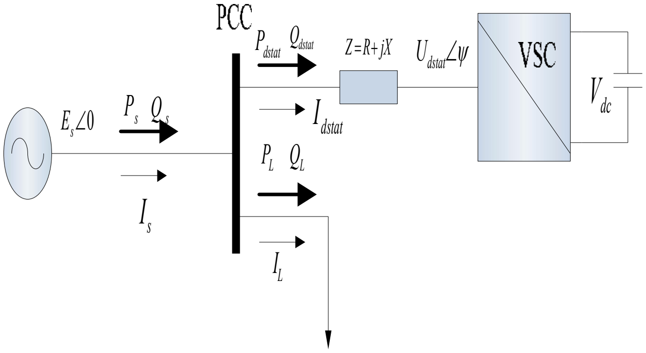
Where, E_s denotes the rms ac grid voltage at the DSTATCOM side with the phase angle of 0°, V_{dstat} is the rms fundamental voltage of the DSTATCOM and ψ is the phase angle between them. The rms source, rms load and the rms DSTATCOM fundamental currents are interpreted as I_s, I_L, and I_{dstat} respectively. The phase angle between the fundamental current and voltage of the DSTATCOM is represented as ψ. The reactive power of load and the DSTATCOM is delineated as Q_L and Q_{dstat}. The ensuing relations are attained by acquainting the modulation index m for the assumed multilevel DSTATCOM.

$$V_{dstat} = m\frac{8V_{dc}}{\pi} \tag{5}$$

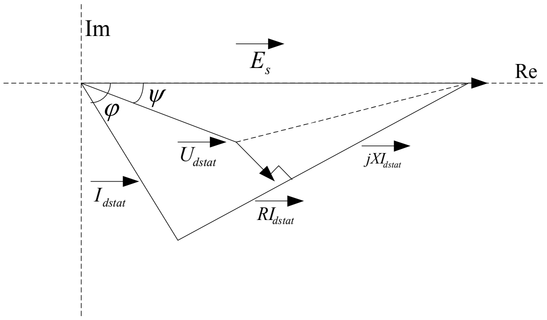
$$P_{dstat} = \frac{8mE_s V_{dc}}{\pi X} Sin(\psi) \tag{6}$$

$$Q_{dstat} = \frac{E_s}{X}\left[E_s - \frac{8mV_{dc}}{\pi} Cos(\psi)\right] \tag{7}$$

In generic, by varying m, phase angle ψ, dc voltage V_{dc} or all the three, the reactive power of the DSTATCOM can be assorted contingent upon the modulation technique. In phase shift modulation (PSM), the reactive power is assorted by varying the dc voltage and the phase angle by custody the modulation index value as constant. On the other hand, in the pulse width modulation (PWM) the reactive power is assorted by varying the modulation index and phase angle by custody the constant dc voltage.



(a)



(b)

Fig. 2 (a) Single line diagram of the shunt connected VSC and (b) Phasor diagram

3.2. *Control Scheme of DSTATCOM*

The main intention of the control scheme is to prohibit the system from collapse under sudden interruptions. Here, the proposed control scheme of DSTATCOM is utilized to enhance the quality of the power supply by performing functions as 1) reduces voltage and current harmonics, 2) balances the source current, 3) enriches the power factor, 4) compensate the voltage disturbances such as sag and swell and also 5) diminishes losses as well as the rating of VSI. In the reactive power control loop, PI controller is utilized which takes error signal δ as an input and the error signal is symbolized as,

$$Err(\delta)\% = \left(\frac{Q_L^* - Q_{dstat}}{Q_{dstat}}\right)\cdot 100 \tag{8}$$

$$Q_L^* = \sum\left(Q_{dstat}, Q_L, Q_s\right) \tag{9}$$

Where, Q_L^* depicts the reference load reactive power, at the steady state condition, $Q_s = 0$ and $Q_L = Q_{dstat}$. By varying the output phase angle ψ within the reactive power generation capacity of the DSTATCOM, the operation is retained at the unity power factor by the control system. The voltage at PCC is evaluated to compute the phase angle ϑ for which phase locked loop (PLL) is applied. By assuming $\psi = 0$ on the outer control loop, the proposed algorithm computes the switching angles α_1 and α_2 with the modulation index m. In PSM, the effective switching angles α_1^* and α_2^* are computed by taking the input as ψ, ϑ, α_1 and α_2 which can accomplish both the harmonic mitigation and the reactive power regulation. The charging and discharging of the dc-link capacitor is caused by varying the phase angle and consequently the voltage at the dc link get varies by using PSM. During this voltage variation, the dc link voltage of each cell has to be balanced for the proposed n-level DSTATCOM. To perform this voltage balancing, the proposed control technique is applied. The optimization technique proposed to balance the voltage is briefly revealed in the succeeding section.

4. Proposed Optimization Techniques

In this paper, a hybrid optimization technique is proposed to mitigate the power quality disturbance in the DSTATCOM with the n-level inverter. Here, the hybrid optimization is the combined performance of both random forest search algorithm and lightning search algorithm (RFLSA) techniques. Here, the proposed technique is utilized for picking the ideal control signal of the n-level inverter based DSTATCOM through trading edges and stage point. At the same time, it is also utilized for setting up the control signals in light of the reactive power deviation and the modulation index value. In the proposed technique, the LSA is used to enhance the learning process of RFSA in view of the minimum error objective function. The RFSA based optimal gain parameter is explained in the following segment.

4.1RFSA based Optimal Gain Parameter

In this section, the optimum gain parameter of PI controller is assayed by the RFSA to provide the control signal of the n-level inverter. Here, the controller parameters such as voltage, current, power losses, real and reactive power values have been scrutinized. Then, the optimal control parameters are attained utilizing the RFSA technique. RFSA is a well known supervised classification algorithm which contrives more number of decision trees and at last, outputs the optimal individual trees in the forest [24-26]. The algorithm steps to optimize the individual trees are inclined beneath,

Step 1: Initialize $'N'$ number of trees in the forest and the parameters such as ψ, ϑ, α_1 and α_2. The input of the algorithm is given as the reactive power deviations and the modulation index to detect the switching angles necessary to optimize the output voltage. K_p and K_i are the gain parameters of PI controller which is randomly generated.

Step 2: The gain parameters are randomly selected to detect the root node by utilizing the best split. The training sets are splitted into subsets such that each subset contains data with the same value for an attribute. These processes are rendered based on the data pickup and it is expressed as,

$$I_g = -\sum_i \frac{|X_i|}{|X|} E(X_i) \tag{10}$$

Where, X is the training dataset, X_i is the subset of the training dataset and the entropy of the set $E(X_i)$ defined as,

$$E(X_i) = -\sum_{j=1}^{n} P_j \log_2(P_j) \tag{11}$$

Where, n is the number of sleep stages to be categorized and P_j is the proportion of sleep stage j in the set (X_i). If the earned information is positive, then the node will split otherwise it will not split and becomes a leaf node. This node is given as an input of the most common sleep stage in the training set. The determination of the best split is known as the number of leaves per tree.

Step 3: The process is replicated until the number of nodes has been reached. By replicating the above process, $'N'$ number of trees can be randomly generated. This randomly created tree forms the random forest. Once the above activity gets achieved, RFSA can able to generate the optimal gain parameters K_p and K_i of the PI controller. For the prediction of the optimal gain parameter, LSA is utilized as per the succeeding section.

4.1. *Prediction using LSA*

In this section, the predication of the optimal gain parameters of the PI controller is performed. It is attained by lessening the error deviation of the reactive power. Then the optimized gain parameter is utilized to expand the finest control signal of the DSTATCOM. By utilizing the optimal control signal of DSTATCOM the power quality of the system gets enriched. The steps to enact the optimal control signal of the DSTATCOM are demonstrated in the following section [27-29].

Step 1: Initialization: Initialize the population size, maximum number of iterations, maximum channel time and the lower and upper bounds of the step leader. The error deviation is given as the input of the algorithm.

$$X = \left|(X_i)^1, \ldots (X_i)^d \cdots (X_i)^n\right| \tag{12}$$

Where, $i = 1, 2, \ldots n$ is the n number of iterations.

Step 2: Random generation: Generate the random number of solution vectors pertinent to population size and the dimension as the step leader (SL).

Step 3: Evaluation: The fitness of the population is evaluated and the required fitness function is given in the ensuing form,

$$F = Min\{\delta(t)\} \tag{13}$$

Where, $\delta(t)$ represents the error deviation of the reactive power. The process gets optimized once the maximum objective function is enacted.

Step 4: Updating: Based on the fitness function, the best and worst step leaders of the input are updated. If the maximum channel time is not reached, erase the worst channel and renovate the solutions direction and the objective function value. The best and worst solution is renovated by,

$$P_l^{sl}(B) = Best\ solution \tag{14}$$

$$P_l^{sl}(W) = Worst\ solution \tag{15}$$

Step 5: Position Updating: The positions of the solution are renovated by utilizing the following equation and evaluate the fitness functions of the new solutions.

$$New\left(p_{sl}^i\right) = p_{sl}^i \pm \exp rand\left(\mu_i\right) \tag{16}$$

Step 6: Discard Worst Channel: The worst channels are eradicated based on the lower energy levels and then evaluate the best channel and rank them based on the optimal solutions.

Step 7: Terminate the Process: If maximum iteration is not satisfied, accession the iteration and channel time and go to step 3. Once the above procedure is completed, save the optimal results and the system is ready to provide the optimal gain parameters of the PI controller. Based on the optimal gain parameters the control signal of the DSTATCOM is elected using the proposed RFLSA technique.

5. Results and Discussion

In this section, with the fault condition the proposed controller execution is dismembered. In voltage regulation the execution of the D-STATCOM controller is occurred along with the harmonic lessening and current compensation. With different test cases, the model is evaluated and their results are investigated which is portrayed as below (h),

Test case 1: Mitigation of power quality under voltage dip condition

Test case 2: Mitigation of power quality under voltage surge condition

Test case 3: Mitigation of power quality under both (dip and voltage surge) condition

The output of proposed technique displays the real and reactive power controlled in the D-STATCOM with different structures like ANFIS, Fuzzy, ANN and the proposed method. The proposed methodology presentations under different test cases are portrayed as follows.

Test case 1: Mitigation of power quality under voltage dip condition

In this section, the simulation began with supply voltage dip is produced and analyzes the voltage dip. Among fault condition the voltage dip arises due to expanded energy utilization and voltage fluctuation in system. The fig. 3 illustrates the source and the load contrast of current and voltage among voltage dip condition. As observed from the figure, under voltage dip condition the amplitude of source current is deviated at 0.2 to 0.3sec from its nominal current by 25%, and also the source voltage amplitude reduced around 25% at 0.2 to 0.3sec from its nominal voltage and the voltage dip is not raised persistently. Since, if it isn't working legitimately it depends on the execution of D-STATCOM working. At that point the voltage dips are repaid by using the ORNN based D-STATCOM controller. From its nominal value by using controller the voltage dip is raised linearly to compensate the load side voltage which is expressed in fig 3(c) and 3(d).Thus the voltage dip is repaid by using multilevel inverter based D-STATCOM controller and their performance is presented in fig. 3(e) and 3(f).

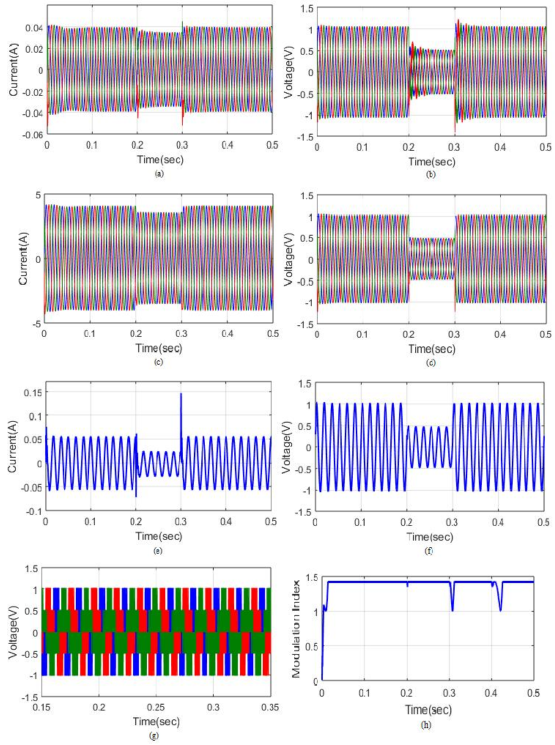


Fig.3 Analysis of proposed method (a) Source Voltage (b) Source Current (c) Load Voltage (d) Load Current (e) D-STATCOM Current (f) D-STATCOM Voltage (g) Inverter Voltage (h) Modulation Index under Voltage dip Condition

In the above image, the D-STATCOM controller performance is dismembered to the extent that the voltage and current midst the voltage dip condition. The proposed controller modulation index produces the optimal control signals to the multilevel inverter at voltage dip condition. Consequentially, the inverter output voltage is quite compensated with optimal control signal. The proposed controller modulation index and inverter voltage in represented in figure 3(g) and 3(h). The controller infused proper compensating current to the PCC and in this manner the voltage in load bus is directed by the D-STATCOM will be elated near the nominal value.

At voltage dip condition the real and reactive power is compared with the current approaches like ANFIS, Fuzzy, RNN and the proposed method. The contrasted graph of the present system with the proposed method is shown up in fig. 4 (a), (b), (c) and (d). Among the transients and steady state condition, remember the 2s time interval of reactive power and the end objective to show that the current and voltage harmonics are satisfied as far as possible.

In the below graph, when t=0s to 0.2s, the reactive power from the D-STATCOM is neither infused nor ingested. At t=0.2s to t=0.32s, the D-STATCOM infused reactive power Qc = - 0.8 p.u into the grid in which Ql is practically equivalent to Qs. The PCC voltage harmonics magnitude in proposed method under voltage dip condition is demonstrates in fig. 4(e). It can be seen that the proposed method mitigates with odd harmonics from 5th to 29th. Hence the THD voltage of proposed method is less than 1% when the D-STATCOM is in operational state. The proposed dc voltage is compared with present systems under voltage dip condition is shown in fig. 4(f). While comparing with present techniques the proposed system shows a decent progression with no overshoot and oscillations. In inductive and capacitive mode, when the D-STATCOM is not in operation the comparison of converter voltage, PCC voltage and the current among fault condition are appeared which is shown in fig. 4(g). While comparing, the converter output voltage is influenced by dc-link capacitor along with operation as continually charging and discharging the capacitor bank.

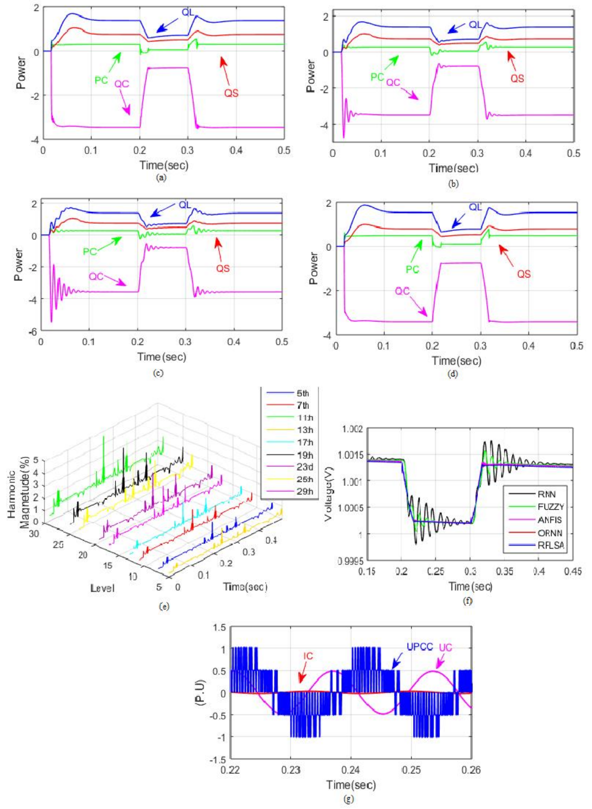


Fig.4 Comparison: (a) ANFIS (b) Fuzzy (c) RNN and (d) Proposed method with Real and Reactive power, (e) PCC voltage dynamic harmonic magnitude in proposed method (f) dc voltage (g) Converter voltage, PCC voltage and current under voltage dip condition

Test case 2: Mitigation of power quality under voltage surge condition

The simulation in this section began with created and analyzed voltage surge. At primarily the voltage surge arises due to sudden lessening of load among fault condition, which impacts the high voltage in system. The fig. 5 illustrates the comparison of current and voltage with source and the load under voltage surge condition. As saw from the figure, under voltage surge condition the amplitude of source current is deviated in 0.2 to 0.3sec from its nominal current by 25%, and also the source voltage amplitude is expanded at 0.2 to 0.3sec around 25% from its nominal voltage and the voltage surge is not compressed persistently. Hence the surge is not repaid if D-STATCOM isn't working properly. At that point the voltage surge are repaid by using the ORNN based D-STATCOM controller. From its nominal value by using D-STATCOM controller the voltage surge is repaid, which is represented in fig 5(a) and 5(b). Essentially, the load side voltage is compensated and from the nominal value practically the voltage surge is reduced by utilizing D-STATCOM controller, which is represented in fig 5(c) and 5(d).

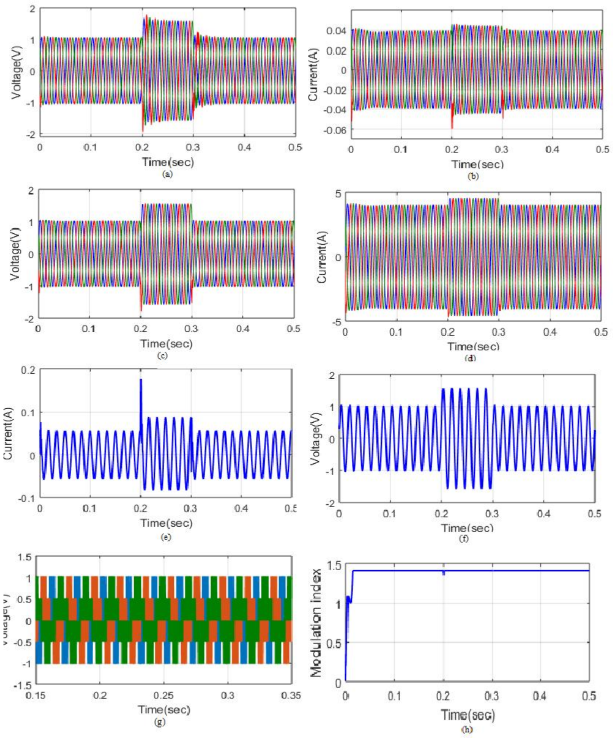


Fig.5 Analysis of proposed method (a) Source Voltage (b) Source Current (c) Load Voltage (d) Load Current (e) D-STATCOM Current (f) D-STATCOM Voltage (g) Inverter Voltage (h) Modulation Index under Voltage surge Condition

In the above figure 5(e) and 5(f), the D-STATCOM controller performance is dismembered to the extent that the voltage and current midst the voltage surge condition. The proposed controller modulation index produces the optimal control signals to the multilevel inverter at voltage surge condition. In this way the inverter output voltage is solely compensated with optimal control signal. The proposed controller modulation index and inverter voltage in represented in figure 5(g) and 5(h). From PCC the D-STATCOM controller ingested proper compensating current and in this manner the D-STATCOM guided the load bus voltage which is deserted near the nominal value.

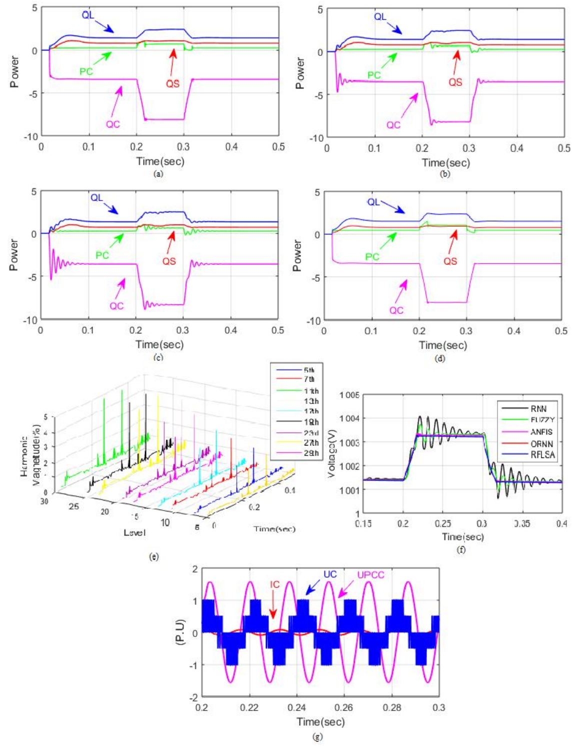


Fig.6 Comparison: (a) ANFIS (b) Fuzzy (c) RNN and (d) Proposed method with Real and Reactive power, (e) PCC voltage dynamic harmonic magnitude in proposed method (f) dc voltage (g) Converter voltage, PCC voltage and current under voltage surge condition

Under voltage surge condition the real and reactive power is compared with the current approaches like ANFIS, Fuzzy, RNN and the proposed method. The contrasted graph of the present system with the proposed method is shown up in fig. 6 (a), (b), (c) and (d). Among the transients and steady state condition, remember the 2s time interval of reactive power and the end objective to show that the current and voltage harmonics are satisfied as far as possible. As per the graph when t=0s to 0.2s, from the D-STATCOM the reactive power is neither infused nor ingested. At t=0.2s to t=0.32s, the D-STATCOM ingested reactive power Qc = - 8 p.u into the grid in which Ql is practically equivalent to Qs. In the course of ingested Qc into the network the proposed system shows a decent progression with no overshoot and oscillations when compared with present techniques. The PCC voltage harmonics magnitude in proposed method under voltage surge condition is demonstrates in fig. 6 (e). In the figure the proposed method mitigates with odd harmonics from 5th to 29th. Hence the THD voltage of proposed method is less than 1% when the D-STATCOM is in operational state. The proposed dc voltage is compared with present systems at voltage surge condition is shown in fig. 6 (f). In inductive and capacitive mode, when the D-STATCOM is not in operation the comparison of converter voltage, PCC voltage and the current among fault condition are demonstrated which is shown in fig. 6 (g).

Test case 3: Mitigation of power quality under both (dips and voltage surge) condition

Both the voltages are analyzed and the simulation began with supply voltage surge and dip is created in this region. Primarily the voltage fluctuation arises due to enlarged energy utilization and power loss in system among fault condition.

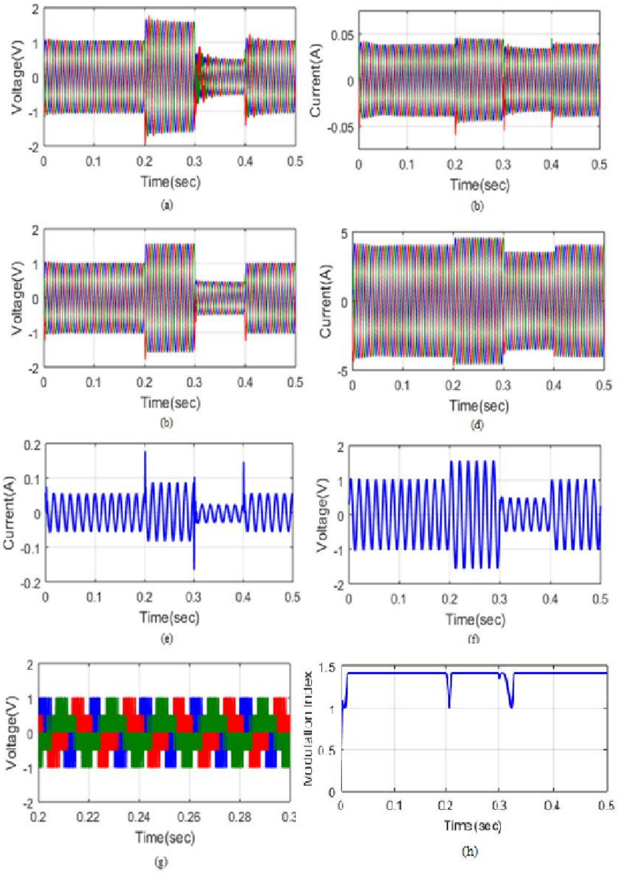


Fig.7 Analysis of proposed method (a) Source Voltage (b) Source Current (c) Load Voltage (d) Load Current (e) D-STATCOM Current (f) D-STATCOM Voltage (g) Inverter Voltage (h) Modulation Index under both (dips and voltage surge) condition

The fig. 7 illustrates the comparison of current and voltage with source and the load under both voltage conditions. As saw from the figure, the amplitude of source current is deviated from its nominal current by 25%, and also the source voltage amplitude is expanded around 25% from its nominal voltage under voltage surge condition and the voltage variation is not allayed persistently. Hence the voltage variation is repaid if D-STATCOM controller is working properly.

From its nominal value by using D-STATCOM controller the voltage variation is repaid, which is shown in fig 7(a) and 7(b). Essentially, the load side voltage is compensated and from the nominal value practically the voltage variation is mitigated by utilizing D-STATCOM controller, which is represented in fig 7(c) and 7(d).In the above figure 7(e) and 7(f), the D-STATCOM controller performance is dismembered to the extent that the voltage and current midst the voltage variation condition. Here, at 0.3s to 0.4s time interval the voltage dip occurs and voltage surge is happen in time interval 0.2s to 0.3s. The proposed controller modulation index produces the optimal control signals to the multilevel inverter at both voltage conditions. In this way the inverter output voltage is solely compensated with optimal control signal. The proposed controller modulation index and inverter voltage in represented in figure 7(g) and 7(h). From PCC the D-STATCOM controller ingested or infused proper compensating current and at this point the D-STATCOM guided the load bus voltage which is discarded near the nominal value. The real and reactive power is compared with the current approaches like ANFIS, Fuzzy, RNN and the proposed method at various voltage conditions. The contrasted graph of the present system with the proposed method is shown up in fig. 8 (a), (b), (c) and (d). Among the transients and steady state condition, remember the 2s time interval of reactive power and the end objective to show that the current and voltage harmonics are satisfied as far as possible. As per the graph when t=0s to 0.2s, from the D-STATCOM the reactive power is neither infused nor ingested. At t=0.2s to t=0.32s, the D-STATCOM ingested reactive power Qc = - 8 p.u into the grid in which Ql is practically equivalent to Qs.

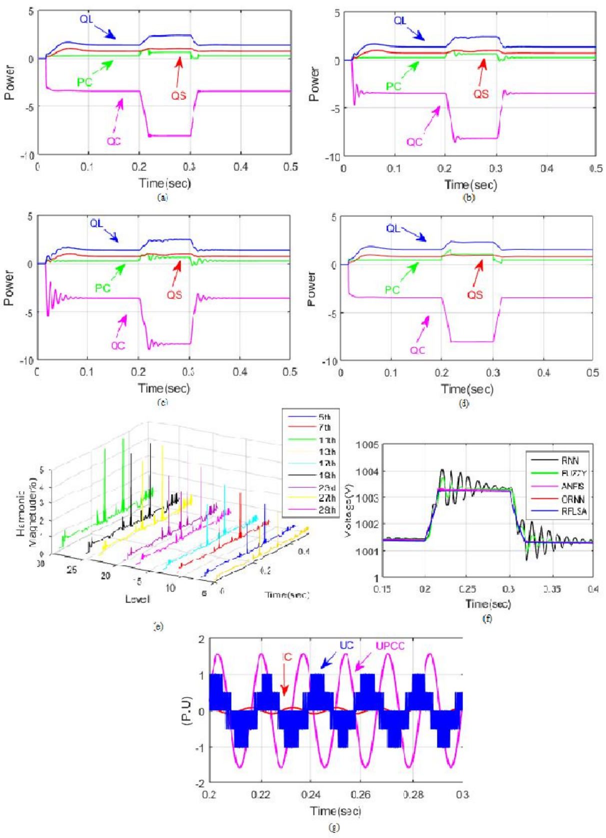


Fig.8 Comparison: (a) ANFIS (b) Fuzzy (c) RNN and (d) Proposed method with Real and Reactive power, (e) PCC voltage dynamic harmonic magnitude in proposed method (f) dc voltage (g) Converter voltage, PCC voltage and current under both (dips and voltage surge) condition

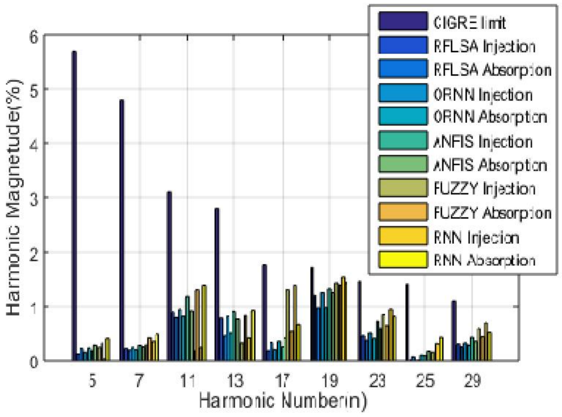


Fig. 9 nth harmonic component imposed by both the grid code

The PCC voltage harmonics magnitude in the proposed method under voltage surge and dip condition is demonstrates in fig. 8 (e). In the figure the proposed method mitigates with odd harmonics from 5th to 29th. Hence the THD voltage of proposed method is less than 1% when the D-STATCOM is in operational state. The proposed dc voltage is compared with present systems at both voltage dip and surge condition is shown in fig. 8 (f). In inductive and capacitive mode, when the D-STATCOM is not in operation the comparison of converter voltage, PCC voltage and the current among fault condition are demonstrated which is shown in fig. 8 (g). . Thus the proposed system shows a decent progression with no overshoot and oscillations when compared with present techniques like ANFIS, Fuzzy and RNN. In the above bar graph, the proposed technique mitigates with odd harmonics from 5th to 29th within the grid limits among transients and also in steady state condition. The grid code requirement in both CIGRE WG 36-05 and the EN 50160 imposed with nth harmonic component which is appeared in fig. 9, where the current music among infused nor ingested of responsive power are compared and the current procedures like ANFIS, Fuzzy, RNN and the proposed.

6. Conclusion

A hybrid technique has been proposed in this paper for the control of DSTATCOM using n-level inverter for mitigating the power quality issues. The hybrid technique is the combined execution of random forest search algorithm and the lightning search algorithm (RFLSA). Here, the proposed technique optimizes the control signal of the n-level inverter by amending the gain parameters of the PI controller. The gain parameters are amended by the RFSA algorithm and its learning process is enhanced by LSA based on the minimum error deviation of the reactive power. Then the proposed technique is realized in MATLAB/Simulink platform and the simulation results have been contrasted with the existing controllers. On comparison, it is confirmed that the proposed technique ensures a better response in change of reference reactive power over the existing techniques.

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