RECENT DEVELOPMENTS OF DSTATCOM WITH OPTIMAL LOCATION & SIZE IDENTIFICATION IN ELECTRICAL DISTRIBUTION SYSTEM

Dheeraj Kumar Dhaked [1*], Dinesh Birla [1*]

[1] *Department of Electrical Engineering, Rajasthan Technical University, Kota, INDIA.*

A R T I C L E I N F O

A B S T R A C T

The optimal utilization of the electrical distribution system (DS) is necessary considering the recent increase of the grid networks. Issues like excessive power loss, voltage fluctuation or regulation, voltage profile problem, reliability, etc. arise due to high construction cost, and power network development. To overcome these issues, the Distributed Static Compensator (DSTATCOM) is worn in the power DS. In the past few years, investigators have practiced locating optimal sites with the size of DSTATCOM with different aspects into consideration. The economic profit, reliability, required quality, and availability are some considerations to find out the size, and optimal site of DSTATCOM. The existing research work can be categorized into five types including artificial neural network supported methodology, analytical approaches, meta-heuristic approaches, sensitivity based approaches, and a method with the combination of sensitivity approaches & meta-heuristic based approaches. The work so carried out by precious investigators' objectives of voltage deviation mitigation, power loss alleviation, reduction of cost of DSTATCOM, enhancement of reliability matrices, and improvement in voltage stability are considered. All methods of DSTATCOM placement are discussed and compared to one another. This paper presents a review for controlling methods and the optimal allocation of the DSTATCOM in DS.

Disciplinary: Electrical Engineering (Power Systems Engineering).

©2020 INT TRANS J ENG MANAG SCI TECH.

1 INTRODUCTION

Increasing economic efficiency and loading capacity of the electrical system have resulted to make use of the transmission system, and DS up to their maximum efficiency, and loading. These can give quality problems related to voltage & current like harmonics in current, poor power factor & voltage regulation, neutral current increase, sag & swell, and flicker in voltage, etc. are faced in DS.

Renewable power sources also increase these problems of the superiority of supply in an electrical system (Goch, Ledwich, 2003). Various PQ issues like load unbalancing, and harmonics can be eliminated by using power electronics converters i.e. DVR (dynamic voltage restorer), DSTATCOM, UPQC (unified PQ compensator), etc. (Taher and Afsari, 2014).

DSTATCOM is a power electronics converter used as a synchronous voltage generator in DS to improve loading efficiency DS. It is classified in three-phase-three-wire (3p3w), and three-phase-four-wire (3p4w) configurations with, and without a transformer. Control techniques like proportional-integral technique, instantaneous reactive power method, synchronous reference frame, neural network, and sliding mode control theory, etc. are used for DSTATCOM (Gupta et. al., 2007).

This paper has reviewed the DSTATCOM, its working, control, applications with classification mainly, and also has significantly surveyed the various sizing & placement techniques of DSTATCOM in DS. The position and size of DSTATCOM can be found according to quality, economic feasibility, required availability, and reliability of the system (Sreenivasrao et. al., 2012). There are various papers published on the placement of DSTATCOM with size, and very few survey papers are published on the placement of DSTATCOM. So, it is a critical need to review the DSTATCOM along with its placement, and size thoroughly with applied methods, algorithms, constraints, and objective function (OF). Since 2015, more than 20 papers have been published on DSTATCOM placement see Figure 1. Various placement methods for DSTATCOM like neural network-based methods, meta-heuristic methods, analytical methods, sensitivity techniques, and amalgamation of sensitivity, and meta-heuristic approaches (Rohilla, and Pal, 2013) are reviewed in this paper.

2   DSTATCOM

"A STATCOM with a pairing transformer, an inverter, and an energy storage mechanism used in DS is termed as DSTATCOM, and it has an arrangement as the STATCOM" (Kannan, and Rengarajan, 2012).
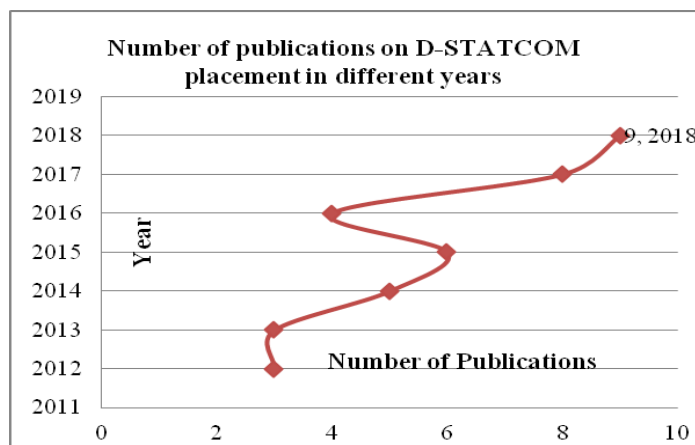

Figure 1: D-STATCOM placement publications during 2011-2019.

2.1   WORKING OPERATION

It is a shunt connected device, consisting of power electronics topology, and utilized in DS. Voltage control as per necessity at point of common coupling (PCC) is the foremost work of DSTATCOM if the battery storage, active power source, or flywheel is connected then active power can also be sent to the DS. Figure 2 shows DSTATCOM connected to nonlinear, and unbalanced loads at PCC, and injecting current. PQ is improved using this in DS with reference to voltage profile,

power factor (PF), voltage stability, etc. Its nature of reactive power absorption and injection with very fast and dynamical responses is helpful in many applications in the DS.

2.2 APPLICATIONS

DSTATCOM feeds current into DS at PCC for helping in harmonics eradication, PF improvement, compensation of neutral current, and LB. The possible application of DSTATCOM is compensation in single-phase micro-grids, reduction in PV power fluctuations, PV inclusion in DS (Kannan, Rengarajan, 2012), voltage support for low voltage system, a hybrid VAR compensator with thyristor switched capacitor (TSC) in DS (Singh et. al., 2014), and alleviation of voltage flicker/sag/swell (Rohilla, Pal, 2013).

2.3 DSTATCOM APPARATUS:

The DSTATCOM contains various components *i.e.* voltage source converter (VSC), transformer, DC bus capacitor, and ripple filter, depicted in Figure 3. To match the inverter output with line voltage a transformer is connected. Three-phase AC voltages are coming through VSC from DC voltages, and a capacitor and reactor are utilized for synchronization to PCC.
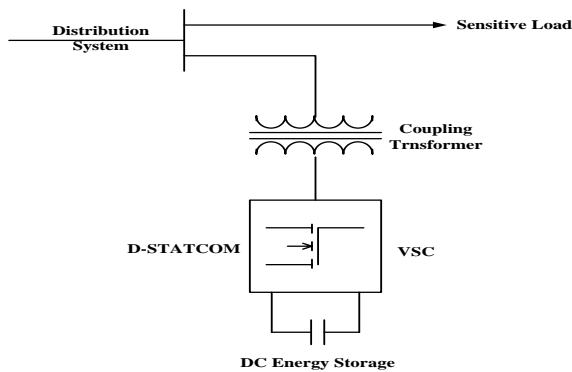

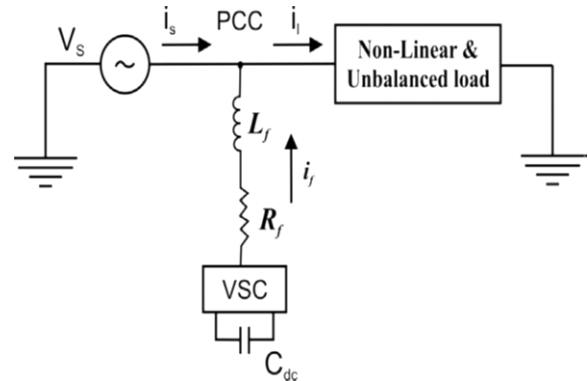**Figure 2**: DSTATCOM configuration in the distribution network.

Figure 3: Single line diagram of DSTATCOM.

2.4 STATCOM CONFIGURATIONS

Based on connection DSTATCOM configuration categorized in 3p3w, and 3p4w DS & further categorized on the base of the type of converter used, the quantity of switching instruments, utilization of transformer for neutral current compensation, and isolation, etc. (Singh et. al., 2014). Here only transformer connections, VSC connections, and several wires are considered for categorization can be further classified on the source and load configurations. The categorization of DSTATCOM is publicized in Figure 4.
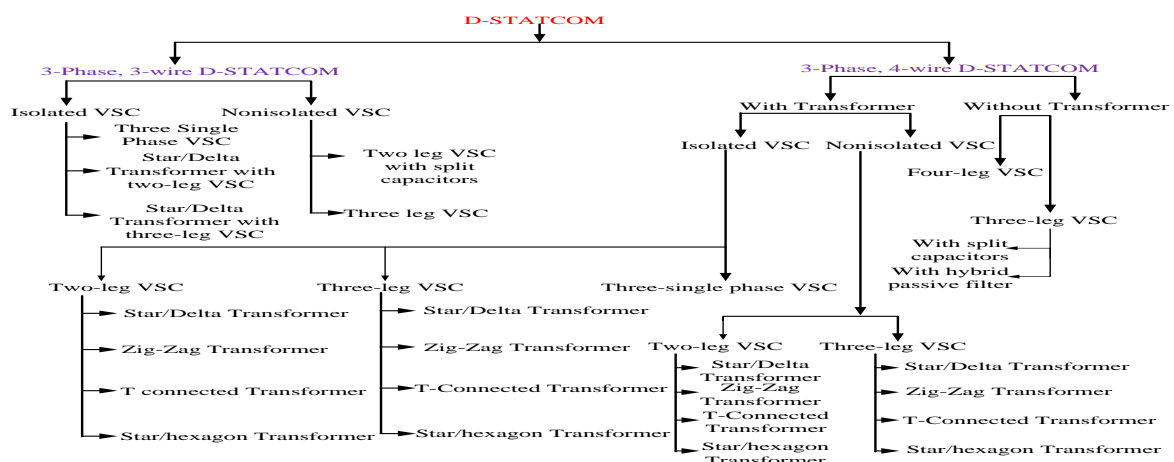

Figure 4: Classification of DSTATCOM configurations.

2.4.1 3P3W CONFIGURATION

Reactive power compensation, harmonic exclusion, PQ enhancement, reactive power fulfillment, and load matching in 3P3W DS can be done by using 3P3W DSTATCOMs. The 3P3W DSTATCOM has different configurations further as isolated, and non-isolated VSC-based DSTATCOM and these can also be further categorized based on connections of the transformer as shown in Figure4. A related work of DSTATCOM configuration was reported by some investigators (Bouafia et. al., 2018; Prasad et. al., 2019; Renukadevi et. al., 2018; Patel et. al., 2018; Bagheri et. al., 2018; Mahela et.al., 2015; Coteli et. al., 2018; Taher et. al., 2013) (Table 1).

Table 1: Assessment of 3P3W DSTATCOM configurations.

S. No.	DSTATCOM topology	No. of semiconductor devices	Transformer
1.	Isolated 3 single-phase VSC	12	3 single-phase units
2.	Isolated 3-leg VSC	6	tar/delta
3.	Isolated 2-leg VSC	4	Star/delta
4.	Non-isolated 3-leg VSC	6	Not required
5.	Non-isolated 2-leg VSC	4	Not required

2.4.2 3P4W CONFIGURATION

3P4W DSTATCOM used to filter-out load current to assemble the requirements related devices connections in the system (Sultana et. al., 2016; Prabu and Muthuveerapan, 2016; Kanwar et. al., 2015). To improve source current, DSTATCOM can be used to tackle the decrease in PF by compensating source current for unbalanced loads by using harmonic compensation, PQ improvement, and cancel out dc offset. The 3P4W DSTATCOM is mainly classified into two kinds based on with, and without a transformer, and further classified on connections type, see Table 2.

Table 2: DSTATCOM classification based on connections.

S. No.	DSTATCOM topology	No. of semiconductor devices	Transformer
1.	2-leg VSC with star/delta tran.	4	Star/delta
2.	2-leg VSC with zig/zag tran.	4	Star/Zig-Zag
3.	2-leg VSC with star/hexagon tran.	4	Star/Hexagon
4.	2-leg VSC with T-connected tran.	4	T-Connected
5.	3-leg VSC with star/delta transf.	6	Star/delta
6.	3-leg VSC with T-connected tran.	6	T-Connected
7.	3-leg VSC with star/hexagon tran.	6	Star/Hexagon
8.	3-leg VSC with zig/zag tran.	6	Star/Zig-Zag
9.	Three-1-ph. VSC	12	3 no. of 1-ph.

2.5 DSTATCOM CONTROL TECHNIQUES

DSTATCOM is used for delivering reactive supply to the system, and active power delivered by the load to stabilize the source current. Controlling of VSC is done by the original frequency element of load by using control techniques. Various control techniques have been used by investigators like Proportional Integral (PI) controller theory, Instantaneous reactive power (IRP) theory, Synchronous reactive frame (SRF) theory, Average unit power factor (AUPF) theory, Instantaneous symmetrical component (ISC), neural network (NN) theory, and sliding mode control (SMC) theory, and other assorted control techniques were used to uphold constant DC bus voltage. Different control techniques used with some discussion of DSTATCOM are presented.

2.5.1 SRF THEORY

Gupta and Ghosh, (2008) proposed an SRF control algorithm for DSTATCOM as a substitute for a standard phase-locked loop (PLL) which is reducing reactive power burden & execution time on

DSTATCOM. SRF technique is used for DSTATCOM control by converting the currents into synchronously rotating d-q axis (Bangarraju et. al., 2014) because it has the benefit of use of 'off the shelf' VSC, the finest possible rating of VSC, reduced kVA rating, and consequently lesser cost. Among the applied techniques (IRP theory, power balance theory, SRF technique, etc.). The SRF method is a simple and most challenging proven controller under numerous operating conditions. The second-order sliding mode controller is projected to control a 3-level 4-leg DSTATCOM in 3p4w DS. The regulator is realized in SRF using the super distortion algorithm realized on the symmetrical mechanism hypothesis (Prabu, Muthuveerapan, 2016). Parks's transformation is used to find d-q frame currents from $\alpha - \beta$ coordinates by using θ as a transformation angle.

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \cos(\theta) & \sin(\theta) \\ -\sin(\theta) & \cos(\theta) \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \tag{1}$$

The low pass filter is used to get the dc components of current, and transformed back to $\alpha - \beta$ coordinates by using reverse Park's transformation.

$$\begin{bmatrix} i_{\alpha dc} \\ i_{\beta dc} \end{bmatrix} = \begin{bmatrix} \cos(\theta) & \sin(\theta) \\ -\sin(\theta) & \cos(\theta) \end{bmatrix} \begin{bmatrix} i_{ddc} \\ i_{qdc} \end{bmatrix} \tag{2}$$

Now, the three-phase reference source current in *abc* coordinates is transformed as

$$\begin{bmatrix} i_{sa} \\ i_{sb} \\ i_{sc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3/2} \\ -1/2 & -\sqrt{3/2} \end{bmatrix} \begin{bmatrix} i_{\alpha dc} \\ i_{\beta dc} \end{bmatrix} \tag{3}$$

2.5.2 ISC THEORY

This theory base switching algorithm is used for DSTATCOM control in 3p4w DS (Zaveri et. al., 2011) for source current balancing, reactive power compensation, and harmonic mitigation in the load connected in delta connection (Jayprakash et. al., 2012).

2.5.3 IRP THEORY

The α–β frame used for calculation of two-phase quantities transformed from three-phase quantities with Clark's conversion (Sreenivasarao et. al., 2012). The α–β frame of currents which are obtained by instantaneous power theory is transformed back to *abc* frame using reverse Clark's transformation technique (Singh, Solanki, 2009; Singh et. al., 2014) that has the advantage of small floor space needed, lesser height, and less in weight. DSTATCOM is not coupled with control variables, and it does not need PLL but the control method is having the adaptive capability, superior dynamic response, and design practice is also effortless (Kannan, Rengarajan, 2012). An innovative approach using negative sequence voltage based practice is worn to control the DSTATCOM with an instantaneous power balancing algorithm (Kannan, Rengarajan, 2012). This methodology is capable to compensate for load voltage harmonics at PCC & can reduce the current, and voltage related problems (Kumar et. al., 2014). A 3-phase infinite level VSI topology-based inverter was used in (Renukadevi et. al., 2018).

2.5.4 AUPF THEORY

Authors have investigated various algorithms with different loading conditions in DS. The result

analysis is done by considering different loadings like balanced source with balanced & unbalanced nonlinear loads, and unbalanced source with balanced & unbalanced nonlinear loads (Kummari et. al., 2012). Authors worked on a fresh methodology to estimate the reference compensation current of 3-p DSTATCOM with twisted utility circumstances at the instantaneous state and compared with other techniques like p-q, SRF, ISC, AUPF Modified SRF & used for THD mitigation (Sahu, Mahapatra, 2014).

2.5.5 PI CONTROLLER

The investigators have used segmented PI with fuzzy controller for DSTATCOM of electric DS and subjected to various normal disturbances in voltage, and current & found the performance of the PI controller is good, which is robust, and appropriate for normal condition but does not tolerate for severe conditions (Liu et. al., 2011). The PI controller is used with a genetic algorithm (GA) to find the optimized values of the PI controller, and effectiveness was proved with the trial, and error method. Losses in DC bus voltage of DSTATCOM can be approximated by using this method. The voltage error in n^{th} sampling is stated as

$$V_{dci(n)} = V^*_{dc(n)} - V_{dc(n)} \tag{4}.$$

The above voltage error signal is progressed into the PI controller, and the output nth sampling is given as

$$I_{p(n)} = I_{p(n-1)} + K_{pdc} \{V_{dci(n)} - V_{dci(n-1)}\} + K_{idc}*V_{dci(n)} \tag{5},$$

where, K_{idc}, and K_{pdc} are the integral, and proportional gains of the PI controller.

2.5.6 NN BASED THEORY

VSC of DSTATCOM was controlled with an Adaline-based neural network which is simple to execute, gives zero phase shift, and faster response, NN, and the fuzzy-based controller was used in (Singh et. al., 2006 & 2013) given rapid response due to parallel processing.

2.5.7 SMC THEORY

This technique is used for balancing source current for positive sequence currents. The control method is explained in Figure 5. The currents source can be considered as

$$i_{sa} + i_{sb} + i_{sc} = 0 \tag{6}$$
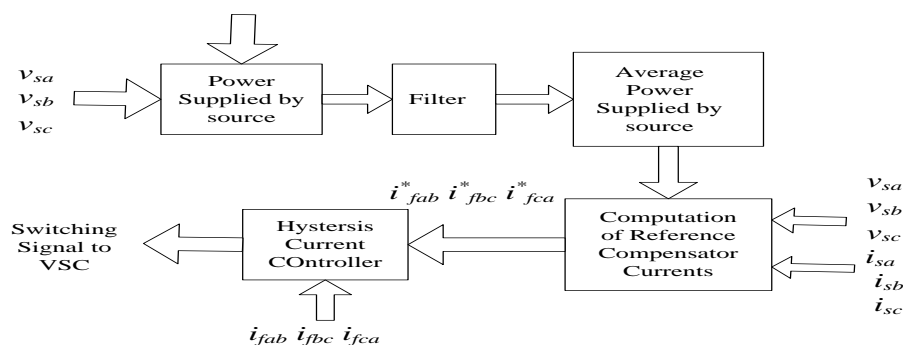

Figure 5: SMC control technique basic flow diagram.

The authors worked on SMC with radial basis function NN which has system robustness, strong adaptableness and integrate the benefits of SMC, and NN so this is an ideal smart controller (Xu et. al., 2010; Gupta, Ghosh, 2008) which improves PCC voltages, THD problem, nonlinearities of load,

Dheeraj Kumar Dhaked, Dinesh Birla

etc. Second-order SMC is proposed to control a 3p4w DSTATCOM connected DS, and compared with first-order SMC, PI controller, and seen that it has high performance under steady-state, and dynamic operations with unbalanced, and faulty systems (Gupta et. al., 2010).

2.5.8 OTHER ASSORTED CONTROL SCHEMES

A DSTATCOM by using Takagi-Sugeno Fuzzy Logic Controller (TS-FLC) was presented for the power-factor amendment, harmonic removal, voltage regulation, and load balancing (LB). Another manuscript presented an accomplishment of a compound spectator based regulation algorithm in three-leg VSI based DSTATCOM in 4-wire DS (Gupta et. al., 2007). Mitra and Venayagamoorthy (2010) have projected adaptive control techniques relied on the artificial immune structure in which PSO was worn to get optimal parameters. DSTATCOM with hardware accomplishment with an adaptive control enhanced linear sinusoidal tracer control algorithm for power factor improvement, LB, harmonic eradication, and zero voltage regulation for nonlinear, and linear loads were used in (Singh, and Arya, 2013).

The DC capacitor voltage equalization regulatory scheme of a diode-clamped five-level inverter-based DSTATCOM was presented in Shukla et. al. (2008). DSTATCOM with improved PLL (EPLL) control scheme to offer load matching, load compensation, power factor modification, and to change the voltages at PCC is investigated by Singh and Arya (2013), learning-based-anti-Habbien control algorithm technique by Arya et. al. (2014). Singh (2018) exhibits the control of the smart PV-DSTATCOM grid coupled framework utilizing an adaptive reweighted zero attracting control algorithm with P&O for a 3-p framework to recover PQ and maintain the 3-phase ac network by providing power-to-grid, and loads. An enhanced PSO method with adaptive inertia weight (w) based on achievement pace is projected to locate the most favorable location of distributed generation (DG), and DSTATCOM in view of security restrictions (Ghatak et. al., 2018). Stockwell-transform (S-transform) based control (Kumar, 2018), an enhanced proportionate normalized least mean square (i-PNLMS) control (Beniwal et. al., 2018), adaptive droop control, a novel adaptive passivity-based control (PBC) (Bouafia et. al., 2018), frequency adaptive disturbance observer approach (Patel et. al., 2018), online reference control (Bagheri et. al., 2018), the neuro-fuzzy controller (Mahela et.al., 2015) was used in papers by investigators for DSTATCOM control. A method to optimize the dc-link voltage of DSTATCOM with load compensation requirements with reduced switch MLI connected to a PV system is proposed (Prasad et. al., 2019). The comparison of different controlling methods of DSTATCOM is compared on LB; harmonic eradication, reactive power compensation, computational difficulty, and neutral current removal at PCC (Coteli et. al., 2018). These methods are compared by using different references in Table 3, also helpful for the selection of DSTATCOM in DS according to its application, and usability.

Table 3: DSTATCOM control methods comparisons.

Technique Used	Load balancing	Harmonic elimination	Reactive power compensation	Source neutral current removal	Computational difficulty
SRF	2	3	3	3	2
IRP	6	3	0	6	5
AUPF	3	6	6	3	4
PI controller	3	0	0	2	2
SC	6	6	6	3	1
NN	6	3	4	3	1

| SMC | 6 | 6 | 6 | 3 | 4 |

*Partial-0, Simple-1, Normal-2, Good-3, High-4, Better-5, Excellent-6

3 PLACEMENT OF DSTATCOM

The maximum utilization of power networks is important with expansion, and improvement of networks. There are various issues like voltage instability problem, excess power loss, voltage profile issues, and reliability problems, etc. mandatory to reduce because of the reason of higher construction cost, and power network development. DSTATCOM as a shunt controller can be placed in DS to solve these issues. To discover the OL of DSTATCOM, a variety of problems should be taken care of as availability, reliability, economic condition, and quality required. The placement of DSTATCOM has taken different following objectives and constraints for examining the problem in DS. The different considered objectives in literature as:

- ❖ Reduction in power losses
- ❖ Up-gradation in voltage stability
- ❖ Enhancement of voltage profile
- ❖ Improvement of reliability in power supply
- ❖ Cost reduction
- ❖ Mitigation in total harmonic distortion
- ❖ Enhancement in LB

Numerous journals published to discover the optimal location (OL) of the DSTATCOM by using different techniques with different loading conditions. Various OFs have considered discovering the OL of DSTATCOM like power loss index, voltage stability index, voltage deviation index, and reliability index, etc. The research carried out for OL finding is classified into five categories that include NN based methods, meta-heuristic methods, analytical methods, sensitivity techniques, and amalgamation of sensitivity, and meta-heuristic approaches.

3.1 NN BASED METHOD

This technique is utilized for modeling of multiple inputs, and output system having nonlinear arrangements. Many applications of NN-based techniques, as reactive power control, fault recognition, voltage control, and detection of voltage instability are also discussed in the manuscript. These methods are capable of optimal placement (OP) of DSTATCOM in DS during fault conditions although. The most favorable situation of DSTATCOM and DVR in DS is done by NN based method to enhance the voltage sag problems during fault conditions. Feedforward neural network was used for finding the OP of DSTATCOM, and DVR (Tanti et. al., 2012).

3.2 META-HEURISTIC BASED APPROACHES

The most commonly used techniques for DSTATCOM allocation are meta-heuristics-based approaches. The methods are stochastic, and inhabitants dependent optimization techniques that are normally competent in managing the multi-objective, multi-modal, distinct, and inhibited problems (Jardehi, Jasni, 2013; Taher, Afsari, 2014). The authors have worked on improved cat swarm optimization (CSO) for synchronized settlement of DGs, and DSTATCOM in electric DS to decrease iron loss, and for better voltage profile (Prabu & Muthuveerapan, 2016). The authors have applied fuzzy-logic dependent ant colony optimization (ACO) technique for DSTATCOM, and PV-array allocation to reduce the losses, improve feeder LB, enhancement of voltage profile, and these objectives were satisfied with fuzzy-logics (Kanwar et. al., 2015).

To solve the DSTATCOM OL problem, Tolabi et. al. (2015) have used the immune algorithm

(IA) with reducing expenditure, power loss, blocking, and improved shape of voltage. Harmony search algorithm (HSA) was used by authors to find OL for DSTATCOM with OF's for copper loss reduction. The consequences are shown in comparison to the immune algorithm (IA) in radial DS to reduce the power losses (Yuvaraj et. al., 2017). Methods based on algorithms like penguin optimization search (Gupta et. al., 2015), hybrid of imperialistic competition, and Nelder-Mead (IC&NM), PSO (Taher, Afsari, 2014), binary gravitational search (BGSA) (Yuvaraj et. al., 2017), firefly (FA) (Kumar, 2016), multi-objective PSO (MOPSO) (Sedighizadeh, Moarref, 2017), bat (BA), non-dominated sorting genetic -II (NSGA-II) (Shahryari et. al., 2018), fuzzy based methodology (Mohammadi et. al., 2017), multi objective genetic (MOGA) (Thirupathaiah, et. al., 2018), differential evolution (DE), and compared with IA (Nazari et. al., 2018), PSO-firefly optimization (Sanam et. al., 2017), crow search (CSA) (Sannigrahi, 2018), imperialist competitive (ICA) (Sedighizadeh, Moarref, 2017), weighted artificial fish swarm (WAFSA) (Umar et. al., 2017), cuckoo search (Tuvaraj et. al., 2017), Multi-objective seeker-optimization (Kumar, 2016) has been used for DSTATCOM placement.

3.3 ANALYTICAL APPROACHES

Normal algorithms consist of analytical types of methods for OL of DSTATCOM as controlling computational resources. The analytical approach is considered to find OL of DSTATCOM for optimum resolution without considering the complexity, and nonlinearity. Some approximations can be used to reduce computational complexity. The analytical approach proposed by authors to find OL of DSTATCOM with power loss, and voltage profile is taken care of in the optimization procedure. The projected scheme is related to GA (Sultana et. al., 2016; Moghtadaei, 2017).

3.4 SENSITIVITY TECHNIQUES

Various papers have used sensitivity approaches for DSTATCOM site selection problems, where the stability index is identified then various potential locations were recognized. Two main OFs were used for DSTATCOM allocation, as described below.

Moghtadaei (2017), Weqar et. al. (2017), Yuvaraj (2017) have worn voltage sensitivity index (VSI) for finding the unhealthiest bus of unbalanced DS. The cost of energy loss, cost of DSTATCOM, load growth (LG), and load model are taken as OF for different loading conditions (Elnady, 2005). Power loss index (PLI), fast voltage stability index (FVSI), and VSI are used as sensitivity indices for DSTATCOM placement during seasonal load changes (Abbasi et. al., 2015). Loss sensitivity factor, and BFOA both have used for DSTATCOM's, and DG's OL for reducing losses with improved voltage profile (Sannigrhi et. al., 2018). DSTATCOM placement was done with VSI for positioning with BA (Devbalaji, 2016). Optimal number, location, and size of DSTATCOMs were found by authors considering DGs existence in radial DS with VSI, and cost reduction (Hussain, Subbaramiah, 2013), Voltage sag minimization used for DSTATCOM placement (Jazebi et. al., 2011). Voltage sag elimination with faults is taken as OF for load buses, and nodes with DVR, and DSTATCOM installation in Tanti et. al. (2012). Voltage profile gain, cost, and THD reduction are used as OFs in the research work. PLI and VSI are used as two OF indices for DSTATCOM allocation (Weqar et. al., 2017), and VSI, active power loss, voltage deviation are taken as sensitivity index in Shahryari et. al. (2018). Various sensitivity indices are used as Index of Voltage profile enhancement, pollution index (PI), index of active, and reactive power loss, and economic index (EI) by Sannigrahi and Acharjee (2018). PLI, LB index, annual cost saving index and voltage profile

index are minimized for OL finding of DSTATCOM in DS (Sedighizadeh, and Moarref, 2017). Power balance constraints, voltage fluctuations limit, reactive power compensation, total annual cost saving (TACS), and VSI are used for calculation of DSTATCOM location. Table 4 elaborates DSTATCOM placement techniques in researches.

Table 4: DSTATCOM placement techniques with applied approaches.

Method	Ref.	System Used	Problem Solved	Approach Discussion
Analytical Approach	Sultana et. al., 2016	IEEE-33 bus system	Power loss, and Voltage profile	Various under/over voltage buses were inspected and compared with well-known GA optimization techniques.
	Hussain and Subbaramiah, 2013	IEEE-33 bus radial network.	Power loss, and voltage profile	Losses in the active power & voltage profile were compared after, and before placement of these devices.
Neural Network method	Sannigrahi et. al., 2018	IEEE-14 bus radial network	Voltage sag problem	Feed-forward NN used, and found that bus which has maximum voltage change in the intended mark is preeminent for DSTATCOM position.
Meta-heuristic-based approach	Parizad et. al., 2010	IEEE-69 bus radial network	Iron loss, and voltage profile	The projected ICSO method/modified CSO is tested with available PSO, and CSO methods, and compared.
	Tolabi et. al., 2015	IEEE 33-bus test system	LB, Power loss, and voltage profile issue	The fuzzy logic-based ant colony optimization (ACO) technique used, and compared with others *i.e.* conventional ACO, and fuzzy-based ACO, GA, PSO technique.
	Yuvaraj et. al., 2015	IEEE 33-bus test system	Iron loss	This manuscript has worked on a harmony search (HS) algorithm which is inspired by a music improvisation procedure.
	Prabu and Muthuveerapan, 2016	IEEE 14, 30, 57-bus system	VPI, and power losses reduction	The authors applied the penguin optimization search algorithm on 14, 30, and 57 IEEE bus structure for approval.
	Hussain, 2013	IEEE 30 bus system	Voltage profile, and active power loss	The authors have used a mix of the IC&NM algorithm.
	Jordehi and Jasni, 2013	IEEE 33 & 69 bus system	cost of DSTATCOM, PLI, Voltage Profile	The results are compared to GA with the proposed Immune Algorithm (IA) for light, medium, and high loading levels.
	Taher and Afsari, 2014	IEEE 12 & 69 bus	Voltage Profile, Copper loss	PSO is used to improve the voltage profile, and to alleviate the copper losses for performance evaluation for dissimilar five cases.
	Sirjania and Jordehi, 2017	IEEE 69 & 81 bus	Voltage Profile, Copper loss	The DE algorithm is used to pick up the voltage profile, and alleviate the copper losses for evaluation, and compared with PSO.
	Jazebi et. al., 2011		Voltage Sag	To alleviate the number of sags circulated through DS the DSTATCOM allocation is completed with BGSA algorithm.
	Salman et. al., 2012	IEEE 16 bus system	PQ, Cost, THD, VPI	performance evaluation with FA, and conclusions revisited with PSO, and GA.
	Moghtadaei and Vafaee, 2017	IEEE 33 bus radial network	voltage profile, Active power loss, and Cost	Projected scheme multi-objective PSO used, and results are evaluated with other practices, and shown that the proposed results are better.
	Yuvaraj et. al., 2017	IEEE 33 bus radial DS	Power Loss, Voltage stability	Bat algorithm was used and reviewed with the IA method.
	Mohammadi et. al., 2017	IEEE 33-bus & 69 bus systems	Cost reduction, Real power loss	Projected method with the fuzzy function of loss sensitivity is utilized for collection of poor nodes, and optimal constraint settings of device alongside optimal finding of tie-switches.
	Thiru et. al., 2018	IEEE 33-bus DS	Total installation cost, and THD	MOGA technique is used in DS for OFs like total installation cost, and THD.
	Shahryari et. al., 2018	IEEE 33, and 94 bus system	active power loss, voltage divergence, and VSI	Using a Monte Carlo-based scheme, and Pareto front solutions are taken through the NSGA-II algorithm which is employed with findings that reduce voltage divergence, losses in active power and enhances the VSI.
	Sanam et. al., 2017	IEEE 30, 33 & 69 bus	VSI, PLI, Energy loss, cost, and Total net profit	DE with backward- forward sweep used for load flow in DS, and compared with IA, the DE method offers reduced CPU time, power loss, OF, and highest TNP.
	Sannigrahi, Acharjee, 2018	IEEE 51 bus system	VSI, PI, line losses, and improvement in financial benefits.	Controlling constraints in MCSA were logically tuned by making them adaptive with iterations at different loading levels. The proposed algorithm is compared with CSA, DE, and HSA algorithms.
	Nazariet.al. 2018		voltage sag, swell, and THD problems	This paper has presented a PSO-firefly optimization to eliminate voltage sag, swell & THD problems, and the outcomes are compared with conventional PID, PSO, firefly methods.
	Sedighizde and Moarref,2017	IEEE 33, and 69 bus systems	PLI, LB, VPI, cost-saving index	The results for ICA are compared with HSA, IA, BA, and BFOA, and found that ICA performance is better.
	Umar et. al., 2017	IEEE 33-bus test system	Voltage profile, and active power loss	WAFSA with an evaluation of steady-state stable load is examined, the results are compared with HSA shown 0.27%

Method	Ref.	System Used	Problem Solved	Approach Discussion
				loss reduction and 5.15% voltage profile enhancement.
	Yuvaraj et. al., 2017	IEEE 33, and 69 bus	Voltage profile	BA used to diminish the losses in power with load variation of 1% from small load to peak load to find the placement of DSTATCOM.
	Kumar, Samantaray, 2016	IEEE 54 bus system	voltage profile control	MOSOA algorithm used for placement with Pareto-optimal solution and results were compared with NSGA-II for DS planning.
	Tejaswani, Susitra, 2020		Bus voltage, and power loss index	Novel swarm astuteness based DA model is compared with PSO, and GA in terms of cost analysis, and convergence speed.
	Yuvaraj et. al., 2017	IEEE 12, 34, and 69 bus	VSI, and load stability index	THE analytical CSA approach is utilized, and results were compared with PSO.
Sensitivity approach	Taher et. al., 2013	25 bus system	Energy loss, Cost, and load sensitivity factor	Using VSI for finding OL in DS. Price of energy loss, Price of DSTATCOM, LG, and load model considered OF for different loading.
	Sannigrahi et. al., 2018		power losses, VSI, and cost	An improved crow search algorithm (ICSA) was used for DSTATCOM placement.
	Gupta, 2015	IEEE 33 bus system	LSF	BFSA for minimizing power losses, and recover the voltage profile was used.
	Devbalaji, Ravi, 2016	IEEE 33 & 119 bus	Voltage sensitivity index	D-STATCOM placement was done for positioning with a bat swarm algorithm.
	Hussain et. al., 2013	IEEE 30 bus system	voltage stability improvement, and cost reduction	The optimal number, location, and size of DSTATCOMs were found by authors considering DGs existence in radial DS.
	Tanti et. al., 2012	IEEE 14-bus system	Voltage sag	Voltage sag elimination was inspected, compared, and shown that DSTATCOM placement is more meaningful.
	Jazebi et. al., 2011	IEEE 69 & 83 bus	Voltage sag	The power balance voltage deviation limit and current limits are the OFs in this study.
	Akbari et. al., 2014	IEEE 33, and 69 bus	Voltage sensitivity index	The highest value for DSTATCOM is selected to find the optimal site solution for DSTATCOM.
	Murthy and Kum 2016	IEEE 33 bus	Voltage sensitivity index	The most unstable bus was chosen for DSTATCOM placement.
	Jain et. al., 2014	IEEE 33 bus system	Voltage sensitivity index	The bus voltage was improved by DSTATCOM placement at an unstable bus in DS.
	Hussain and Visali, 2012	IEEE 33 bus system	VSI, FVSI, CPLS, VSEI, and PSI	The best place for DG and DSTATCOM outcome is a considerable decrease in power loss was obtained.
	Weqar et. al., 2017	IEEE 33 bus DS	PLI, and VSI	PLI and VSI are used as two OF indices for DSTATCOM allocation.
	Shaharyari et. al., 2018	IEEE 33 &94-bus system	VSI, and Active power loss	VSI and active power loss are a major point to achieve the proposed method. The changes in loads were compensated with the MCS technique.
	Sannigrahi, Acharjee, 2018	IEEE 51-bus system	VSI, Pollution Index (PI), Power Loss, and EI	Various sensitivity indices are in the paper by authors for finding the most favorable settlement of DSTATCOM.
	SedighizadM., 2017	IEEE 33, and 69 bus	PLI, load balance, Cost saving, VPI	Various indices for finding the most favorable settlement of DSTATCOM in DS.
	Yuvaraj, et. al., 2017	IEEE 33, and 69 bus	VSI, load balance, Cost saving	Various indices were used as indices for site finding of DSTATCOM.
	Yuvara et. al., 2017	IEEE 12, 34 &69 bus	LSF & VSI	LSF & VSI were used by authors to find the optimal position for DSTATCOM.
	Gupta, Kumar, 2018	UK 38 bus practical system	Loss reduction, PLI	Power loss is computed by load flow methods at all nodes, and the highest PLI value node is the best fit for the DSTATCOM installation.
	Tiwai, Ghatak, 2017	IEEE 33 bus radial network	VPI, Loss reduction	VPI and Loss Reduction are OFs for DSTATCOM placement in DS, and the working platform of MIPOWER was used for analysis.

4 OBJECTIVE, AND CONSTRAINTS OF DSTATCOM PLACEMENT

Based on many papers, a range of objectives have been taken to examine the DSTATCOM placement issue.

4.1 POWER LOSS MITIGATION

Placement of DG, and DSTATCOM for single load level, and varied load levels were considered for observation in manuscripts with load uncertainties (Bagherinasab et. al., 2013) in the meshed network for a case study with seasonal LG. power changes are also considered, with, and without load, and reconfiguration is considered in (Sannigrahi, Acharjee, 2018).

4.2 VOLTAGE PROFILE ENHANCEMENT

For placement of DSTATCOM the voltage profile improvement objective is taken in various papers (Hussain, 2013; Chabok, 2016) with load levels, and other researchers have used the same objectives.

4.3 VOLTAGE STABILITY ENHANCEMENT

Voltage has to be constant during the operation of electrical systems so voltage stability enhancement is used as OF (Jain et. al., 2014; Hussain, Visali, 2012).

4.4 COST MITIGATION

The cost has been an important constraint so this objective is also considered in various research articles for DSTATCOM placement.

4.5 PQ IMPROVEMENT

PQ is to be maintained during working hours of electrical networks so it's used as OF (Farhoodnea et. al., 2013; Bagherinasab et. al., 2013).

4.6 OTHER

Various other OFs are considered like system efficiency improvement (Farhoodnea et. al., 2013; Bagherinasab et. al., 2013), IRP improvement, power stability index, reliability improvement, voltage sag reduction, and THD reduction, etc. for DSTATCOM size, and placement in DS. Various equality and inequality constraints are also considered for DSTATCOM placement issues including

- ➤ Power balance
- ➤ Reactive power compensation
- ➤ Voltage deviation limit
- ➤ DSTATCOM capacity restrictions,
- ➤ Current limit
- ➤ Cost limitations

5 FUTURE SCOPE

Involvement of renewable energy resources (RER's) is escalating on daily basis in utility grids with LG and the intermittent nature of these RER's affect the PQ in terms of voltage regulation problems, neutral current compensation problems, LB issue, THD problem, power factor and voltage profile deterioration problems in DS etc. So, the future research will be mainly focused on RER's and their applications with DSTATCOMs.

- ➤ The DSTATCOM can be a perfect option to solve these above-mentioned issues effectively.
- ➤ The implementation of RER's with DSTATCOM in DS should be explored.
- ➤ Most authors have used light, medium and peak load levels and they have not considered radially increasing load in DS. The small changes in load can affect size and location of DSTATCOM so the radial change should be considered for loading changes.

- Various studies have considered a single DSTATCOM for power loss reduction while multiple DSTATCOM's can also be considered and their result may compare.
- More than one DSTTACOM and DG can be considered to find the most favorable size and place for all loading conditions. This multiple device implementation will improve the result and research will be clearer and more practical.
- All the authors mainly worked with balanced DS in DS for DSTATCOM allocation but unbalanced load should also be considered for future research purpose.
- PQ issues have THD as its main problem but this research of optimal allocation has not been considered THD for PQ. This should add for PQ enhancement in future research for DSTATCOM allocation.
- The research carried out on DSTATCOM placement by different countries affiliated authors has been shown in fig. 6. There are various countries are focusing on the problem and proposing some novel solution that worth to publish in literatures.

Numerous optimization techniques have been applied for DSTATCOM placement and results were discussed and compared but performance of technique regarding speed and accurateness should be considered and compared for further research aspect.

6 CONCLUSION

A thorough literature survey of DSTATCOM and its control techniques are carried out with a detailed review of the devices used for PQ enhancement, and system reliability, along with its control techniques. Various control topologies like PI controller theory, IRP theory, SRF theory, neural network theory, and sliding mode control theory to keep the dc bus voltage constant have been compared and discussed which is helpful for a selection of it. The paper has also discussed the selection of OL for DSTATCOM units in DS. Based on papers reviewed, optimization techniques have improved a very small in unit size, and location for DSTATCOM. Various techniques for OL finding are compared, and various papers with DSTATCOM placement, constraints, and objectives are also discussed but authors have used only a single DSTATCOM unit for examination, and multiple units can be considered for improvement in DS. The research is mainly emphasized on a balanced system, and unbalanced systems can be considered for future research purposes.

7 AVAILABILITY OF DATA, AND MATERIAL

Information can be made available by contacting the corresponding author.

8 REFERENCES

Ãbano, A. Valderr, Ramirez, J. M. (2010). D-statcom regulation by a fuzzy segmented {PI} controller. *Elect Power Syst Res,* 80(6), 707-15.

Abbasi, A-R, Khoramini, R., Dehghan, B. (2015). A new intelligent method for optimal allocation of d-statcom with uncertainty. *J Intel Fuzzy Syst*, 29(5), 1881-88.

Akbari-Zadeh, M-R., Kokabi, R., Gerami, S. (2014). D-statcom allocation in DS considering load uncertainty. *J Intell Fuzzy Syst*, 27(2), 691-700.

Arya, S., Singh, B., Chandra, A., Al-Haddad, K. (2014). Learning-based anti-Hebbian algorithm for control of d-statcom. *IEEE Trans Ind Electron*, 61(11), 6004-12.

Bagheri, M., Nurmanova, V., Abedinia, O., Naderi, M. S., (2018). Enhancing PQ in Microgrids With a New Online Control Strategy for d-statcom Using Reinforcement Learning Algorithm. *IEEE Access*, 6(1), 38986-96.

Bagherinasab, A., Bagheri, M.Z. Khalid, S.A. (2013). OP of d-statcom using hybrid genetic, and ant colony algorithm to losses reduction. *Int J Applied Power Eng*, 2(2), 53-60.

Bangarraju, J., Rajagopal, V., Jayalaxmi, A., (2014). Unit template SRF theory-based control algorithm for d-statcom. *J Inst Eng*, 95(2), 135-41.

Beniwal, N., Hussain, I., Singh B. (2016). Implementation of d-statcom with i-PNLMS Based Control Algorithm under Abnormal Grid Conditions. *India Int Conf. on PE,* India.

Bouafia, S., Benaissa, A., Barkat, S., Bouzidi, M. (2018). Second-order sliding mode control of 3-level 4-leg d-statcom based on ISC theory. *Energy Syst*, 9(1), 79-111.

Chabok, B. S., Ashouri, A. (2016). OP of d-statcom into the radial distribution networks in the presence of DGs. *Am J Elect Electron Eng*, 4(2), 40-48.

Coteli, R., Açikgöz, H., Dandil, B., Tuncer, S. (2018). Real-time implementation of 3-level inverter-based d-statcom using a neuro-fuzzy controller. *Turkish J Elect Eng & CS*, 26(1), 2088-2103.

Devbalaji, K., Ravi, K. (2016). Optimal size, and siting of multiple DG, and d-statcom in radial DS using BFOA. *ASEJ*, 7(3), 959-71.

Farhoodnea, M., Mohamed, A., Shareef, H. (2013). Optimum d-statcom placement using firefly algorithm for PQ enhancement. *Int Power Eng & Opt Conf, Malaysia*, 98-102.

Ghatak, S. R., Sannigrahi, S., Acharjee, P. (2018). Comparative Performance Analysis of DG, and d-statcom Using Improved PSO Based on Success Rate for Deregulated Environment. *IEEE Syst J*, 12(3), 2791-02.

Ghatak, S.R., Sannigrahi, S., and Acharjee, P. (2018). Comparative Performance Analysis of DG, and d-statcom Using Improved PSO Based on Success Rate for Deregulated Environment. *IEEE Syst J*, 12(1), 2791-2802.

Gupta, A. R., Kumar, A. (2015). Energy savings using d-statcom placement in the radial distribution system. *Procedia Comput Sci*, 70(1), 558-64.

Gupta, A.R., Kumar, A. (2018). OP of d-statcom using sensitivity approaches in meshes DS with time variant load models under load growth. *A Sh Engg J*, 9(4), 783-99.

Gupta, R., Ghosh, A. (2008). Frequency-domain characterization of SMC of an inverter used in d-statcom application. *IEEE T. Circ Syst I: Regul Pap*, 53(1), 662-76.

Gupta, R., Ghosh, A., Joshi, A. (2010). Multi band hysteresis modulation, and switching characterization for SMC cascaded MLI. *IEEE Trans Ind Elect*, 57(1), 2344-53.

Hussain, S., Subbaramiah, M. (2013). An analytical approach for optimal location of D-STATCOM in radial DS. *Int Conf on En Eff Tech for Sust, Nagercoil, India*, 1365-69.

Hussain, S., Visali, N. (2012). Identification of weak buses using Voltage Stability Indicator, and its voltage profile improvement by using D-STATCOM in radial distribution systems. *IOSR J Electr Electron Eng.*, 2(4), 17-23.

Jain, A., Gupta, A., Kumar, A. (2014). An efficient method for d-statcom placement in radial DS. *India Int Conf on PE, India*, 1-6.

Jazebi, S., Hosseinian, S., Vahidi, B. (2011). D-statcom allocation in distribution networks considering reconfiguration using differential evolution algorithm. *Ene Conv. Man*, 52(7), 2777-27.

Jordehi, A. R., Jasni, J. (2013). Parameter selection in particle swarm optimization: a survey. *J Exp Theor AI*, 25(4), 527-42.

Kannan, V. K., Rengarajan, N. (2012). Photovoltaic based d-statcom for PQ improvement. *Int J Elect Power En Syst*, 42(1), 685-92.

Kanwar, N., Gupta, N., Niazi, K. (2015). Improved cat swarm optimization for simultaneous allocation of d-statcom, and DGs in DS. *J Ren Energy*, Jaipur, 1-10.

Kumar, D., Samantaray, S.R. (2016). Implementation of multi-objective seeker-optimization-algorithm for optimal planning of primary distribution systems including d-statcom. *Elect Power Energy System*, 77(1), 439-49.

Kumar, P., Singh, A., Kumari, N. (2014). p-q theory based modified control algorithm for load compensating using d-statcom. *Int conf on harm, and qual of po*wer, 591-95.

Kumar, R. (2018). Control of d-statcom Using S-Transform. *IEEE Inno Smart Grid Tech-Asia (ISGT Asia)*, 226-31.

Kummari, N., Singh, A., Kumar, P. (2012). Comparative evaluation of d-statcom control algorithms for load compensation. *Int conf on harmonics, and quality of power*, 299-306.

Liu, J., Xu, Z., Huang, L. (2011). Study on adaptive pi controller of d-statcom. *Strategic technology*, 1(1), 456-59.

Mahela, O. P. Shaik, A. G. (2015). A review of d-statcom. *Renew and Sust Energy Reviews*, 50(1), 531-46.

Mitra, P., Venayagamoorthy, G., (2010). An adaptive control strategy for d-statcom applications in an electric ship power system. *IEEE Trans Po Elect*, 25(1), 95-104.

Moghtadaei, A., Vafaee, M.H. (2017). Optimal Multi-objective Placement, and Sizing of Multiple DGs, and d-statcom via MOPSO. *Majlesi J En Manag*, 6(2), 35-40.

Mohammadi, M., Abasi, M., Rozbahani, A.M. (2017). Fuzzy-GA based algorithm for OP, and sizing of d-statcom for loss reduction of DS considering reconfiguration. *J Cent South Univ*, 24(1), 245-58.

Murthy, V., Kumar, A., (2013). Comparison of optimal DG allocation methods in radial DS based on sensitivity approaches. *IJEEPS*, 53(1), 450-67.

Nazari, M.H., Khodadadi, A., Lorestani, A., Hosseinian, S.H., & Gharehpetian, G.B. (2018). Optimal multi-objective d-statcom placement using MOGA for THD mitigation, and cost minimization. *J Intel & Fuz Syst*, 35(1), 2339-48.

Parizad, A., Khazali, A., Kalantar, M. (2010). OP of DG with sensitivity factors considering voltage stability, and losses indices. *Proc ICEE*, 848-55.

Patel, S. K., Arya, S., Maurya, R., Chitti Babu, B. (2018). Control Scheme for d-statcom based on Frequency Adaptive Disturbance Observer. *JESTPE*, 6(3), 1345-54.

Prabu, J., Muthuveerapan, S. (2016). Optimum Placement, and sizing determination of DG, and d-statcom using penguins search optimization algorithm. *IJIRSET,* 5(1), 6675-80.

Prasad, K. K., Myneni, H., Kumar, G. S. (2019). PQ Improvement, and PV Power Injection by d-statcom with Variable DC Link Voltage Control from RSC-MLC. *IEEE Trans Sust Energy*, 10(2), 876-85.

Renukadevi, V., Jayanand, B. Sobha, M. (2018). A DC-DC converter-based infinite level inverter as d-statcom. *Int Trans Elect Energ Syst*, 29(1), 1-13.

Rohilla, Y., Pal, Y. (2013) T-connected transformer incorporated 3-leg vsc based 3p4w d-statcom for PQ improvement. *Nirma Univ Int Conf on Engg (NUiCONE)*, 1-7.

Sahu, G., Mahapatra, K. (2014). A novel control strategy of d-statcom for load compensation under distorted utility condition. *Int Conf on Adv in Elect Engg*, 1-6.

Salman, N., Mohamed, A., Shareef, H. (2012). Reliability improvement in DS by OP of d-statcom using binary gravitational search algorithm. *Prz Ele*, 88(1), 295-99.

Sanam, J., Ganguly, S., Panda, A. K., Hemanth C. (2017). Optimization of Energy Loss Cost of DS with the OP, and Sizing of d-statcom Using DEA. *Arab J Sci Eng*, 42(1), 2851-65.

Sannigrahi, S., Acharjee, P. (2018). Implementation of Crow Search Algorithm for Optimal Allocation of DG, and d-statcom in Practical DS. *Int Conf on Power, Inst, Control, and Comp, Thrissur, India*.

Sannigrhi, S., Ghatak, S. R., Acharjee, P. (2018). Strategically Incorporation of RES, and d-statcom for Techno-Economic-Environmental Benefits using Search Space Reduction Based Improved CSA. *IET Gen, T&D*.

Sedighizadeh, M., Moarref, A.E. (2017). The Imperialist Competitive Algorithm for optimal Multi-Objective Location, and Sizing of d-statcom in DS Considering Loads Uncertainty. *INAE Letter*, 2(1), 83-95.

Shahryari, E., Shayeghi, H., & Moradzadeh, M. (2018). Probabilistic, and Multi-Objective Placement of d-statcom in DS Considering Load Uncertainty. *Elect Po Comp, and Syst*, 46(1), 27-42.

Shukla, A., Ghosh, A., Joshi, A. (2008). Control schemes ford capacitor voltages equalization in diode-clamped multilevel inverter-based d-statcom. *IEEE Trans Po Del, 23*(2), 1139-49.

Silva, A. J. da, Oliveira, W. R.de. (2016). Comments on quantum ANN with applications. *Inf Sci*, 370(1), 120-12.

Singh, B. (2018). Control of Grid Tied Smart PV d-statcom System Using an Adaptive Technique. *IEEE Trans Smart-grid*, 9(5), 3986-93.

Singh, B., Adya, A., Mittal, A., Gupta, J.R.P. (2006). Neural network based d-statcom controller for 3p3w system. *PEDES*, 1-6.

Singh, B., Arya, S. (2013). Adaptive theory-based improved linear sinusoidal tracer control algorithm for d-statcom. *IEEE Trans Po Elect*, 28(8), 3768-78.

Singh, B., Arya, S. (2013). Implementation of 1-phase enhanced phase-locked loop-based control algorithm for 3-phase d-statcom. *IEEE Trans Power Deliv*, 28(3), 1516-24.

Singh, B., Arya, S., Dube, S. Chandra, A., Haddad, K. Al. (2013). Implementation of d-statcom using neural network based radial basis function. *Ind appl soc meet, Vista*, 1-8.

Singh, B., Arya, S., Jain, C. (2014). Simple peak finding control algorithm of d-statcom for PQ enhancement. *IET Power Electronics*, 7(1), 1736-46.

Singh, B., Solanki, J. (2009). A comparison of control algorithms for d-statcom. *IEEE Trans Ind Elec*, 56(1), 2738-45.

Sirjania, R., Jordehi, A. R. (2017). OP, and sizing of d-statcom in electric distribution networks: A review. *RSE&R,* 77(1), 688-94.

Sreenivasarao, D., Agarwal, P., Das, B. (2012). Neutral current compensation in 3p4w systems: a review. *El Pow Sys Reviews*, 86(1), 170-80.

Sultana, B., Mustafa, M., Sultana, U. (2016). Review on reliability improvement, and power loss reduction in DS via network reconfiguration. *RSE&R*, 66(1), 297-310.

Taher, S. A., Afsari, A. R. (2013). Optimal allocation, and sizing of d-statcom by immune algorithm in DS including DG. *Soft Comp J*, 2(2), 2-15.

Taher, S. A., Afsari, A. R. (2014). Optimal location, and sizing of d-statcom in DS by IA. *IJEPES,* 60(1), 34-44.

Tanti, D., Verma, M., Singh, B. (2012). OP of custom power devices in Power System Network to Mitigate Voltage Sag under Faults. *Int J PE&D Syst*, 2(3), 267-76.

Tejaswani, V., Susitra, D. (2020). Dragonfly Algorithm for Optimal Allocation of D-STATCOM in Distribution Systems. *AI, and Ev Comp in Eng. Sys, Adv in Int Sys, and Comp*, 1056(1), Springer, Singapore.

Thirupathaiah, M., Venkata Prasad, P., Ganesh, V. (2018). Enhancement of PQ in Wind Power DS Using Hybrid PSO-Firefly based d-statcom. *IJRER,* 8(2), 1148-54.

Tolabi, H.B., Ali, M. H., Rizwan, M. (2015). Simultaneous reconfiguration, OP of d-statcom, and photovoltaic array in a DS based on fuzzy-ACO approach. *ITSE,* 6(1), 210-18.

Umar, M., Bakare, G.A., Shehu, M.A., Abubakar, U. (2017). Dstatcom Placement in DS using weighted Artificial Fish Swarm Algorithm. *Int Conf on ET for Nat Dev, Nigeria*, 926-931.

Weqar, B., Khan, M. T., & Siddiqui, A. S. (2017). OP of DG, and d-statcom in radial DS. *Smart Science*, 6(2), 125-133.

Xu, Y., Ma, C., Yang, L., Gong, Z., Pu, H., Zhang, Z. (2010). Study on SMC with rbf network for d-statcom. *Int Conf on E-Product E-Service, and E-Entertainment*, 1-5.

Yuvaraj, T., Devabalaji, K., Ravi, K. (2015). OP, and sizing of d-statcom using Harmony Search algorithm. *En Procedia*, 79(1), 759-65.

Yuvaraj, T., Ravi, K., & Devabalaji, K.R. (2017a). Optimal Allocation of DG, and d-statcom in Radial DS Using Cuckoo Search Optimization Algorithm. *Model Sim in Engg, 1*, 1-11.

Yuvaraj, T., Ravi, K., Devabalaji, K. (2017b). D-statcom allocation in DS considering load variations using bat algorithm. *ASEJ,* 8(3), 391-403.

Yuvaraj, T., Ravi, K., Devabalaji, K.R. (2017c). D-statcom Allocation in the Radial DS with Different Stability İndices using Bat Algorithm. *Gazi Univ J Sci*, 30(4), 314-28.

Zaveri, T., Bhavesh, B., Zaveri, N., (2011). Control techniques for PQ improvement in delta connected load using d-statcom. *Int Elect Mach Drives Conf*, 1397-1402.

Dheeraj Kumar Dhaked pursues a Ph.D. at Rajasthan Technical University, Kota, India. He got his B.Tech in Electrical Engineering from Rajasthan Technical University, Kota, and completed his M.Tech in Power System Engineering. His research interest includes FACTS Controller in Transmission System, Microgrid, Biomass Energy, Renewable Energy, Solar Power, Battery Charging-Discharging, Artificial Intelligence, Artificial Neural Network and Power Converter.

Professor Dr.Dinesh Birla works at the Department of Electrical Engineering at the Rajasthan Technical University, Kota. He got a Ph.D. from IIT Roorkee. His research includes Power System Protection, Power Electronics & Renewable Energy.