"ENHANCEMENT OF POWER QUALITY USING NOVEL KH-F TECHNIQUE IN SLV DISTRIBUTION SYSTEM CONNECTED TO DISTRIBUTED GENERATION"

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Abstract : As the Power demand increases day by day alternate source of energy need to be injected to the existing grid. The need of pure power with smartness is increasing in the distribution system. SLV feeder erected in Mysuru district, Karnataka, India is the pilot smart grid project undertaken by the state government is taken has the case study. To meet the demand solar photovoltaic system and wind generator are the DG which is finding its wide potential in this area. As the complexity of grid enhances the power quality issues such as voltage sag, voltage swell and harmonic arises. To overcome the power quality issues at utility many types of power controllers are developed in which DSTATCOM and DVR places an important role in eliminating the voltage fluctuations and sudden current surges that affect the consumer products. This can be done effectively by designing control technique for DSTATCOM and DVR to compensate the reactive power developed in the grid. Various control technique has been discussed in the literature, a new technique, Krill herd fuzzy controller (KH-F) optimization discussed in this paper shows the effectiveness in eliminating the power quality issues. This in turn increases the smartness and efficacy of SLV distribution system by supplying quality power to the consumer; it is implemented using MATLAB simulink**.**

IndexTerms **- SLV Feeder, harmonics, DSTATCOM, DVR and DFIG.**

1. INTRODUCTION

The Indian power sector is growing day by day, to meet this generation capacity is enhanced and it is about 344GW during the year 2018.The 344GW is achieved by all sources of energy including conventional energies. In this Solar Photovoltaic and Wind has contributed about 18% of generation but still power depict by 10.2% to meet the peak demand. To improve the demand and deliver quality power to the consumer India has launched first smart grid pilot project in Mysuru, by integrating technologies of SCADA, peak load management, agriculture distribution system management and renewable integration with grid . At present it takes care of billing, transformer protection, automatic metering system, load management and monitoring. But to alleviate power quality issues steps are not been implemented [1].

In this paper, a novel Fuzzy bases PI controller with Krill optimization is used to control the DSTATCOM and DVR .The DSTATCOM and DVR is injected to the SLV smart feeder with solar and wind DG . Analysis on power quality when wind and solar is injected to the distribution system is studied. The elimination of Power quality issues with DSTATCOM and DVR is shown [4][5].

2. DISTRIBUTED GENERATION

Karnataka government has taken up many initiatives to accelerate the potential of renewable energy sector in the state. The government is aiming to be a leading Renewable State in the country at present it is at 3rd place. In 2018, the state has allotted 493 projects of 10736.8MW capacity solar photovoltaic projects across 30 districts and State is also rich with Wind power generating farms in comparison with other states in India. State currently has installation capacity of 1,368W.

2.1 Distributed Solar Photovoltaic Generation System

The Solar photovoltaic (PV) power generation is growing considerably worldwide. It is attracting many developers and consumers because of its size and pollution free operation .Technologies have been changing in PV generation to meet the increasing demand. The block diagram distributed solar generating system is as shown in Figure.1 [2].

The distributed solar generating system dats is extracted from the site which is located at Belakavadi village in Shivansamudram project in Malavalli taluk of Mandya district. The solar panel considere is Mono crystalline solar panels the most efficient of about 12-15% on average type having better performance in low light .

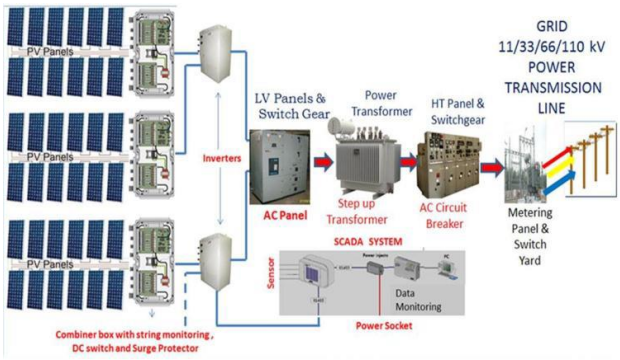

Fig1: Block Diagram of Distributed Solar Generating System

Table 1: Distributed Solar Panel Specification

Type	Mono crystalline
No's of Module per MW	4512
Watt	220W
Voltage	360V
Current	7.6A
Efficiency	14.3%
Tilt angle of PV Module	15 Degree
Output of PV array	250KW
Protective Device	400V under voltage relay

The solar specification is has mentioned in table 1 below the mathematical modeling of solar double diode is shown in figure 2 with MPPT system is designed based on the following equation (10).

The mathematical modeling of solar double diode is shown in Figure 2 with MPPT system is designed based on the following equation(10).

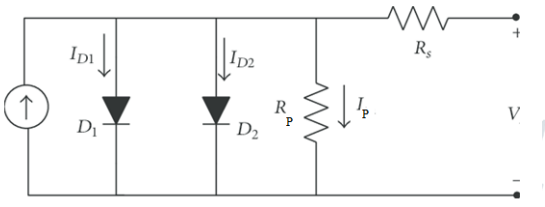

Fig2: Double Diode Model of Distributed Solar System

$$I_{PV} = I_{ph} - I_{s1}\left[exp\frac{V+I_{PV}.Rs}{a} - 1\right] - I_{s2}\left[exp\frac{V+I_{PV}.Rs}{a} - 1\right] - \frac{V+R_sI_{PV}}{R_P} \quad (1)$$

The MPPT modeling is done based on equation (2) using pertub and observer algorithm,

$$I_{mpp} = I_{ph} - Io\left[\exp\frac{Vmpp+Impp.Rs}{a} - 1\right] - \frac{Vmpp+R_sImpp}{R_P} \quad (2)$$

The Matlab simulink modeling has been done by considering the above equation and specification of panel and 1MW power is injected to the power grid. The Matlab model of distributed solar photovoltaic system is as shown in Figure 3.

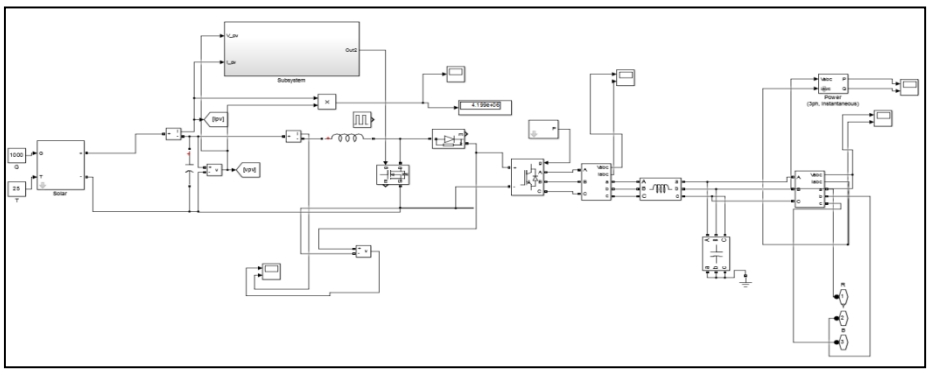

Fig. 3: Simulated AC Model of Double Diode PV with MPPT

The voltage and current output of distributed solar system is shown in Figure 4, the active and reactive power output is shown in Figure 5.

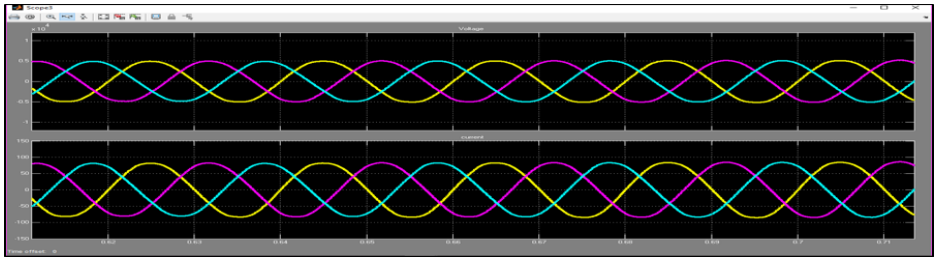

Fig. 4: Voltage and Current Output of PV System

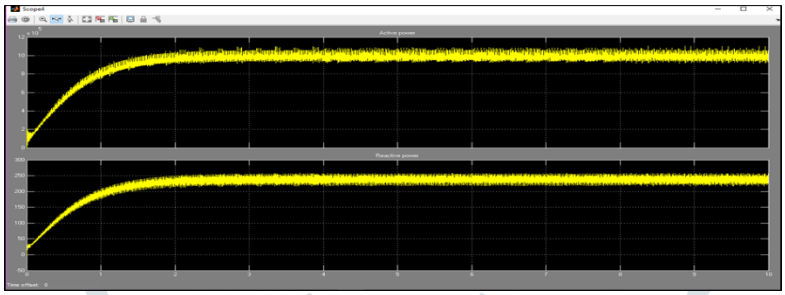

Fig. 5: Active and Reactive Power Output of PV System

The above modeled distributed solar photovoltaic generating system of having an active power of 1MW is injected to the SLV feeder distribution grid and its impact is discussed in results.

2.1 DFIG Wind Generation System

The Karnataka State is rich in Wind power generating farms in comparison with other states in India. State currently has installation capacity of 13236MW. In this work DFIG with rotor side control using Voltage side controller with PI controller .The Simulink model of VSC control DFIG is as shown in Figure 6 , output waveforms stator voltage, stator current and rotor current is shown in Figure 7 and Figure 8 shows the active and reactive power output [3].

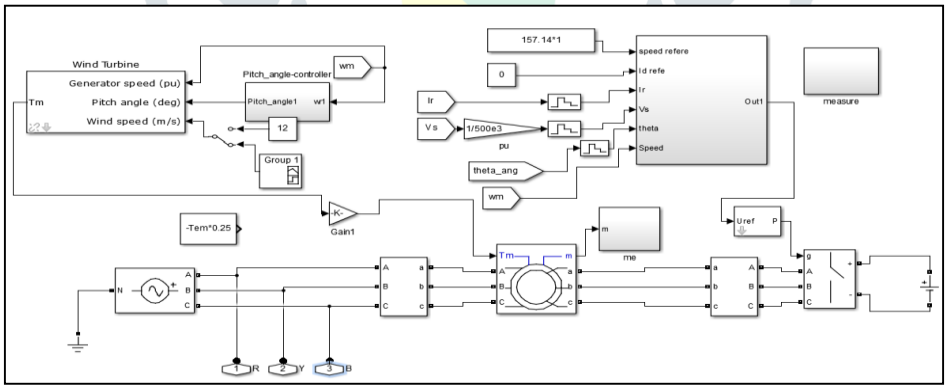

FIG 6: Simulink Model of VSC Control of DFIG.

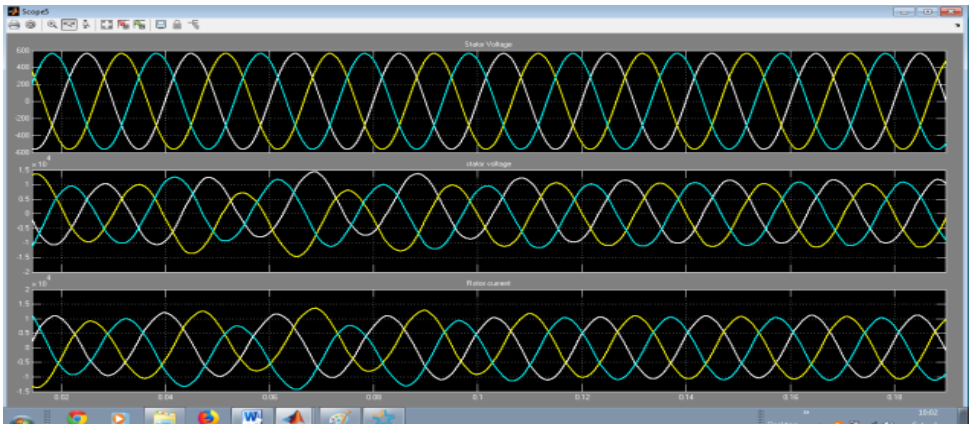

Fig. 7: Output Waveform of Vs,Is, Ir of DFIG.

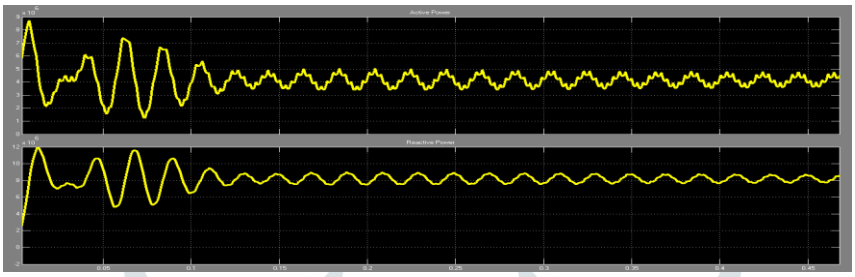

Fig. 8: Active Power and Reactive Power Output of DFIG.

An active power of 0.5MW is obtained from the DFIG model designed is injected to the SLV feeder distribution grid and its impact is discussed in results.

2.2 DYNAMIC STATIC COMPENSATOR (DSTATCOM)

The DSTATCOM works on the principle of injection of harmonic current to the grid through active filters of the grid; by injecting the harmonic current a pure sinusoidal voltage waveform is attained and the improved power quality are accomplished Figure 9 shows the basic function diagram of DSTATCOM control techniques[6].

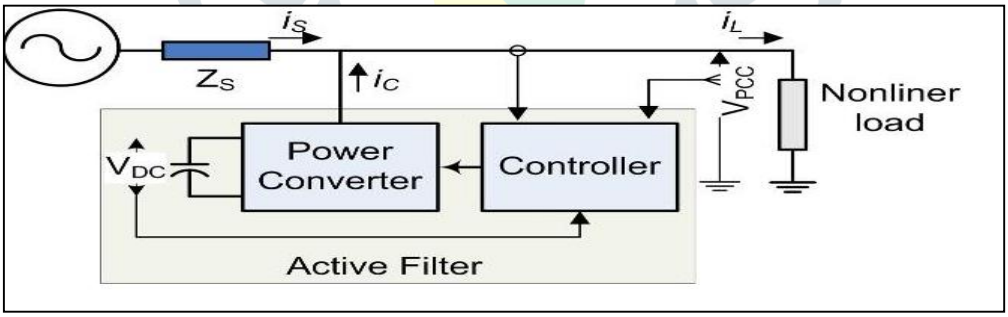

Fig 9: DSTATCOM Functional Diagram

Figure 9 shows a load with supply voltage .The current i_L is the current flowing through the nonlinear load with harmonics. To compensate harmonics in i_L an active filter generates suppressing current i_S, applying KCL we get,

$$i_S = i_L - i_c \qquad (3)$$

The current in 3-phase is given by,

$$i_{sR} = \frac{P_L}{V^2} U_R; \qquad i_{sY} = \frac{P_L}{V^2} U_Y; \qquad i_{sB} = \frac{P_L}{V^2} U_B; \qquad (4)$$

Where

$$V^2 = \frac{1}{T} V_R^2 + V_Y^2 + V_B^2 \qquad (5)$$

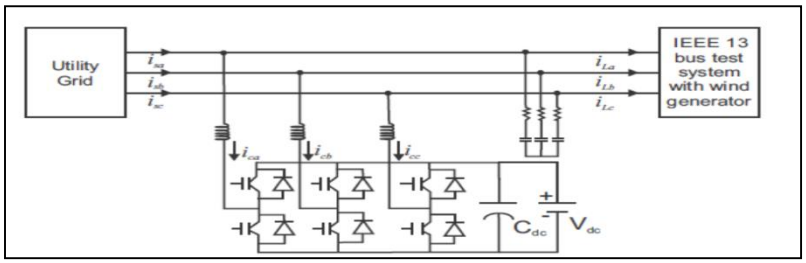

Fig 10: 6 PWM for DSTATCOM

The Figure 10 shows the 6 pulse PWM inverter, the operation of the DSTATCOM working mainly based on the exchange of real and reactive powers between the distribution grid and inverter output of the DSTATCOM. The equation of P and Q power is given by equations 10 and 11respectively

$$P = \frac{V_{PCC}\, V_C\ sin\propto}{X} \quad (11)$$

$$Q = \frac{V_{PCC}\,(V_{PCC} - V_C\ cos\propto)}{X} \quad (12)$$

2.3 Dynamic Voltage Restorer (DVR)

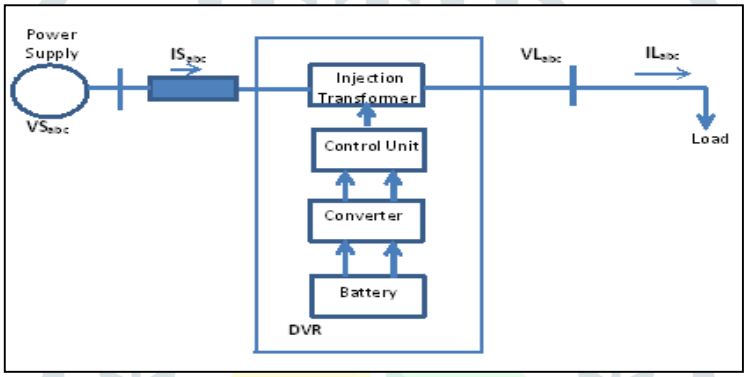

Fig 11: Functional Diagram of DVR

As the name itself suggest dynamic voltage restorer (DVR) is one of the excellent powerful electronics device which has a dynamic voltage restoration capability. The restorer is best suited to safeguard the very sensitive customer connected appliances from short duration of voltage fluctuation like voltage sag /swell. The dynamic voltage restorer is suitable for placing between the power supply and the customer load point. It act has an antibiotic to the voltage fluctuation by injecting a voltage on the system disturbed system by compensating the affected load voltage as in Figure 10.

2.4 Proposed Novel Method KH- F Controllers for DSTATCOM and DVR

The main aim of this work is to choose a technique for enhancing the performance of DSTATCOM and DVR by designing a control strategies used for calculation of reference current and the triggering circuit designed for firing the circuit. The DSTATCOM and DVR both works on the same principle voltage source controller. In this way, the objective function is framed based on equality and inequality constraints. It is given as[8],

$$F_t = \sum_{i=1}^{n} V_{ref} - V_t \quad (13)$$

Where V_t is terminal voltage, the variable are updated to enhance the performance of the dc link voltage. The block diagram in of the proposed Krill herd-Fuzzy algorithm is as shown in Figure 12

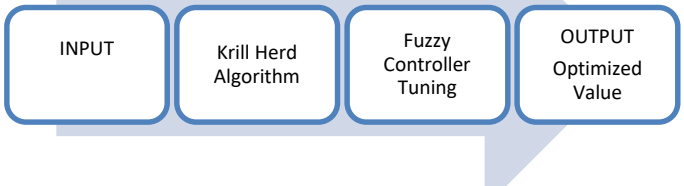

Fig 12 : Block Diagram of KH-F

The swarm hunter (predators) is considered as a starting point of optimization algorithm because the hunter confiscate the krill individuals, condense the krill density and increases the distance of krill from the food locality.
The factors effecting krill positions and movements are:
a) Movements tempered by krill individuals (N_i)
b) Hunting activity (F_i)
c) Arbitrary diffusion (D_i)

It is formulated using the following Lagrangian model:

$$\frac{dX_i}{dy} = N_i + F_i + D_i \quad (14)$$

Steps for KHA

Step1: Initialize the number of iteration and population size by initializing speed of foraging speed, maximum induced speed and maximum iteration number.

Step 2**:** calculate the fitness by finding the Krill present position.

Step 3: Estimate the movement of krill with respect to the mentioned operational factors

a) The first term N_i in the above equation(14) represents the motion of the krill , the direction of the individuals is found out by estimating considering direction(α), local effect and target effect as equation shown below;

$$N_i^{new} = N^{max}\alpha_i + \omega_n N_i^{old} \quad (15)$$

Where

$\alpha_i = \alpha_i^{local} + \alpha_i^{target}$(Direction of initial and target position)

N_i^{new}-> New krill speed induced, N^{max}->Max speed, N_i^{old}->last motion of the krill.

The sensing direction from krill and neighbour of the KH is given by d_s

$d_{s,i} = \frac{1}{N}\sum_{j=1}^{N}\|X_i - X_j\|$

If ($X_i - X_j$) < $d_{s,i}$ then i and j are the krill neighbour.

b) The second term F_i in equation (14) represents the hunting or foraging motion, the behaviour of krill to attack towards the food is given by the following equations:

$$F_i^{new} = V_f\beta_i + \omega_f NF_i^{old}$$

Where

$\beta_i = \beta_i^{food} + \beta_i^{best}$

V_f-> Forging speed, ω_f-> weights, β_i^{food}-> attractive food, β_i^{best}-> best food.

c) The third term D_i in equation (14) is an arbitrary diffusion or physical diffusion speed, expression is as follows

$D_i = D^{max}\delta$

Step 4: If the condition is not met go to step 2.
Step 5: The new position of the krill individual is obtained
Step6 : The scaling of Δt is done using Fuzzy Logic Controller which is used as a tuner to obtain the Best solution of dc link voltage.

The KH movements of the krill swarm process will approach always towards the best fitness by using local and global conditions.
From t to t+Δt vector position is given by:

$$BEST\ solution\ = (X_t(t + \Delta t) = X_t + \Delta t\ \frac{dX_t}{dt}$$

The equation gives the updated position of the krill. Where Δt is a scaling parameter of the speed given by :

$$\Delta t = C_t \sum_{j=1}^{NV} (UB_j - LB_j)$$

The Krill herd search starts without having any information about optimal solution, high random search property of Krill discover local optimal value and also by setting the optimal value in lowest quantity the Krill herd algorithm lay emphasis on manipulation of optimal value using local search . The fuzzy controller is used has tuner to tune between the investigating and manipulation and hence gives the best values. The Pseudo code for Krill herd-Fuzzy algorithm is as follows and the flow chart is as shown in Figure 13,

1. Start
2. Initial Parameter setting
3. Pre-calculation
4. Initial Krill position
5. Movements induced
6. Forging motion
7. Physical diffusion
8. Update Krill position
9. Update the current best
10. Tuning using fuzzy controller
11. Optimized best solution
12. End

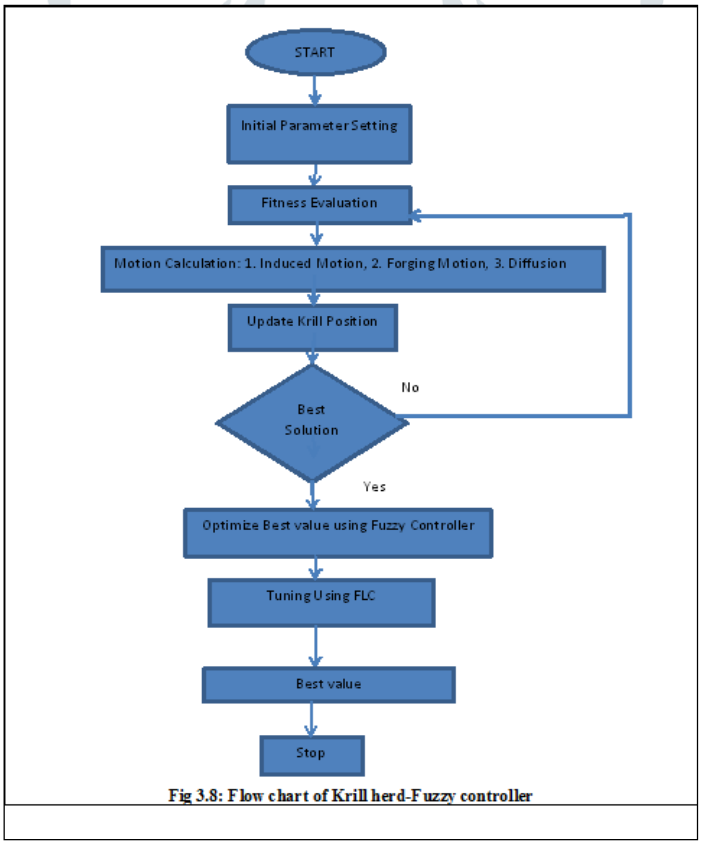

Fig 13: KH-F FLOW CHART

2.5 RESULTS AND DISCUSSION

2.5.1*Performance of DSTATCOM Using Novel KRILL HERD-FUZZY(KH-F) Controller:* The main aim of this work is to choose a technique for enhancing the performance of DSTATCOM and by designing a control strategies used for calculation of reference current and the triggering circuit designed for firing the circuit for SLV feeder system as shown in Figure 14a and 14b .

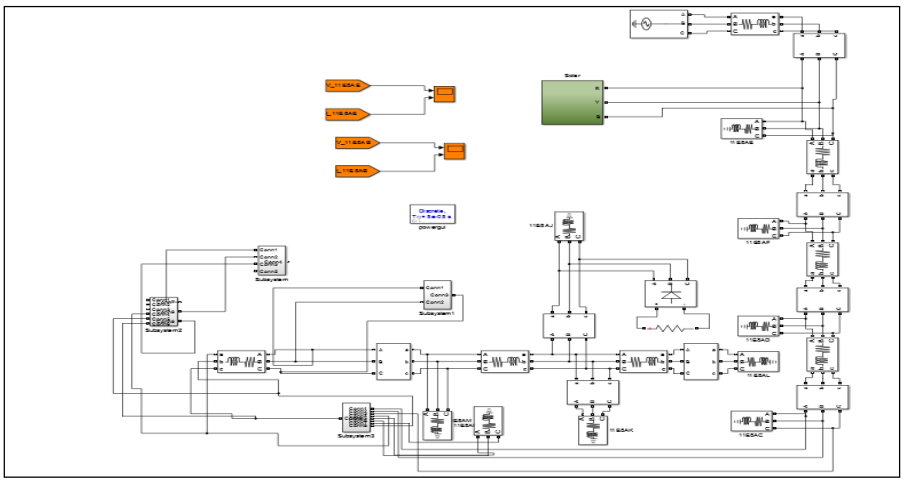

Fig 14a: SLV Feeder with DG

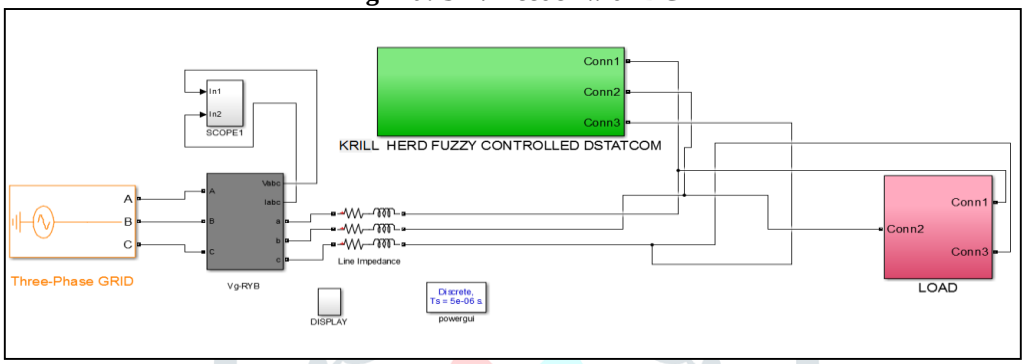

Fig 14b: SLV Feeder with KH-F DSTATCOM

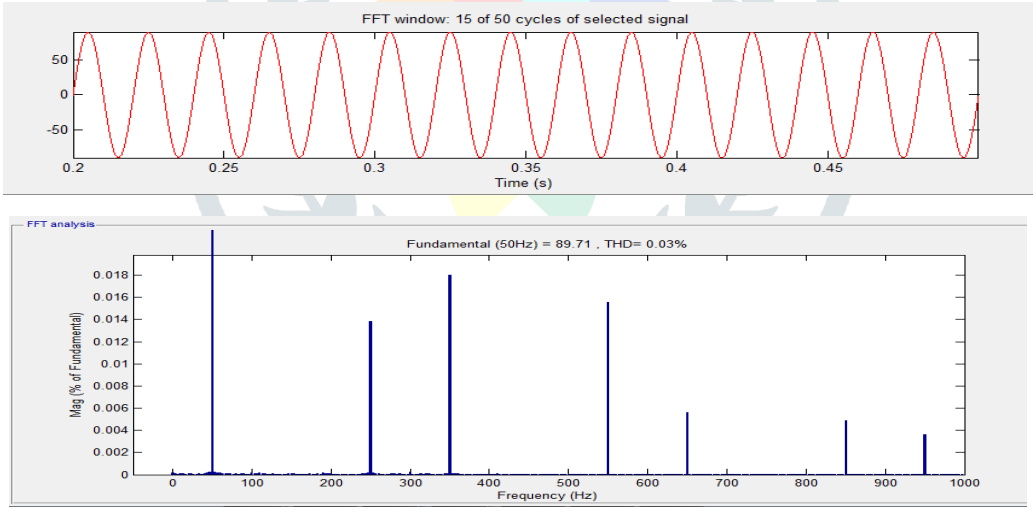

Fig 15: THD Obtained in SLV Feeder with KH-F DSTATCOM

Figure 15 shows the THD obtained in SLV Feeder with KH-F technique developed DSTATCOM , Figure 16 shows the voltage and current variation with KH-F DSTATCOM injection on grid side, Figure 17 shows the Grid V&I, Load Current and Injected Current Waveform. The table 2 shows the comparison of THD obtained from various techniques and it is clear from the table that the technique developed reduces the harmonics in SLV feeder line with DSTATCOM.

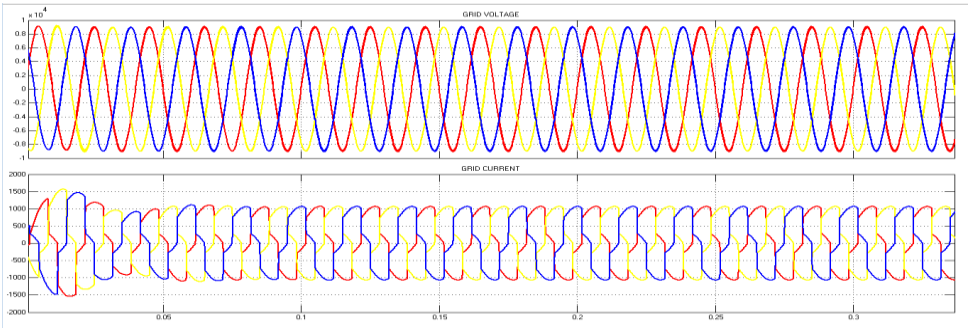

Fig 16: Grid Side Voltage and Grid side Current with KH-F Controller

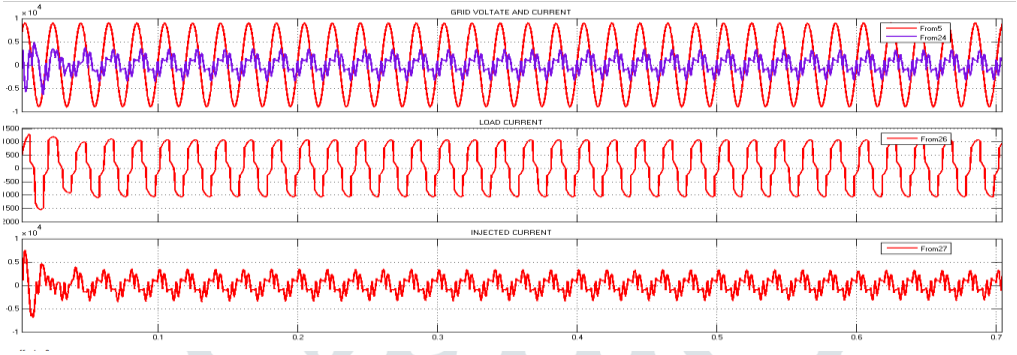

Fig 17: Grid V&I, Load Current and Injected Current Waveform

Table 2: Comparison of THD obtained from different VCS control of DSTATCOM

	With SRF	With PI	With Fuzzy-PI	With KH-F
% Current THD	18.81%	10.16%	2.55%	0.03%

2.5.2. SIMULATION OF DVR CONTROL TECHNIQUE

The dynamic voltage restorer is suitable for placing between the power supply and the customer load point. It act has an antibiotic to the voltage fluctuation by injecting a current on the system disturbed system by compensating the affected load voltage.

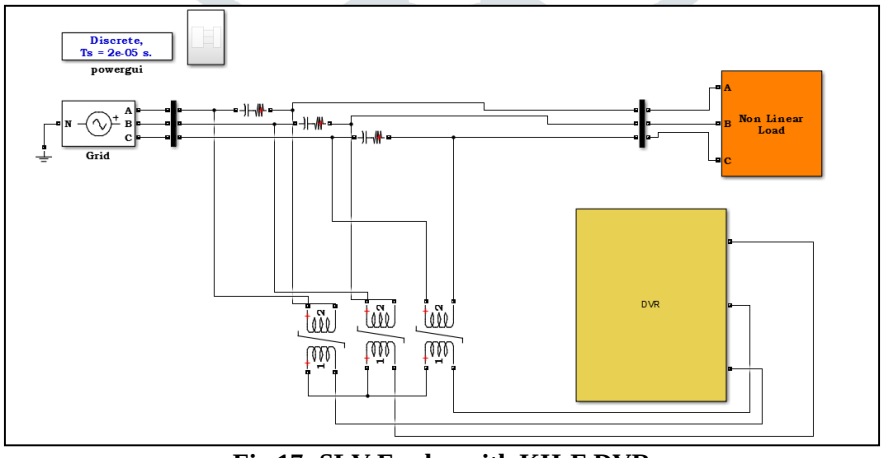

Fig 17: SLV Feeder with KH-F DVR

Performance of DVR Using Novel KH-F Controller: The Krill herd search starts without having any information about optimal solution, high random search property of Krill discover local optimal value of DC link voltage, and also by setting the optimal value in lowest quantity the Krill herd algorithm lay emphasis on manipulation of optimal value using local search . The fuzzy controller is used has tuner to tune between the investigating and manipulation and hence gives the best values the algorithm used for this is as in Figure 3.8 a flow chart. The Voltage THD of load voltage obtained using KH-F controller is 0.08% as shown in Figure 18. The input

and output voltage and current from 11KV source is as shown in Figure 19 and 20 respectively, grid, load and injected voltages are shown in Figure 21.

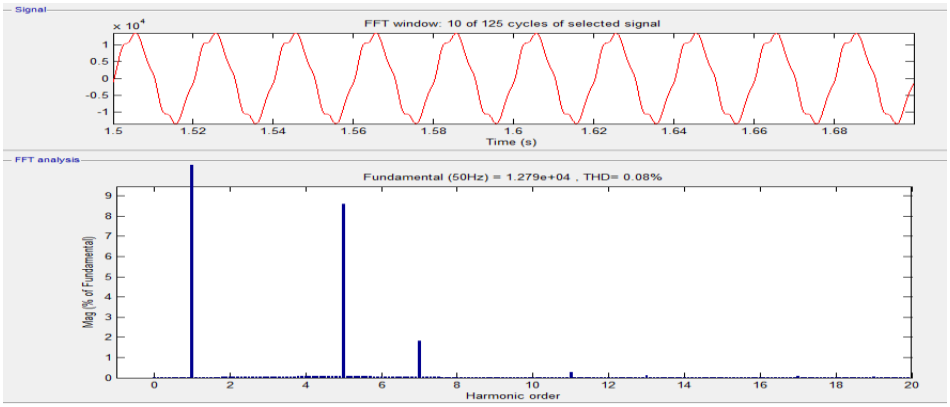

Fig 18: THD Obtained in SLV Feeder with KH-F DVR

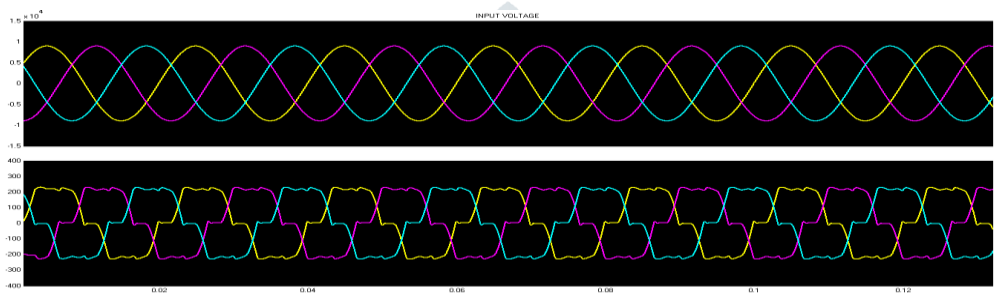

Fig 19: Input Voltage and Current from 11KV Source

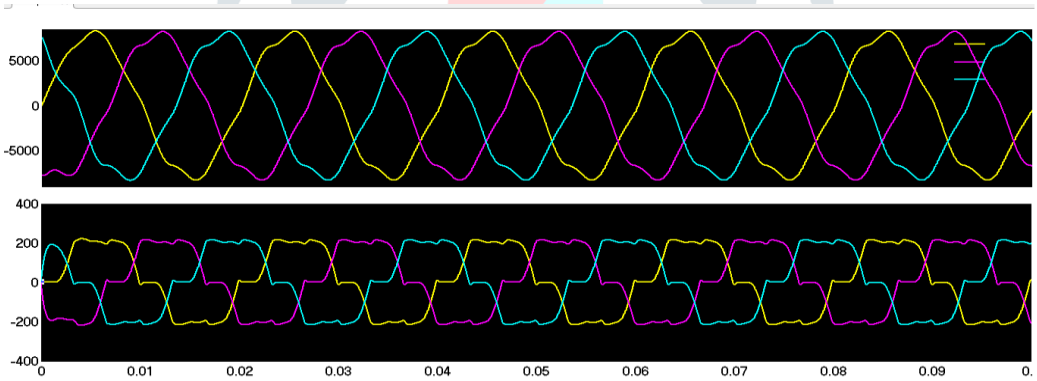

Fig 20: Input Voltage and Current from 11KV Source

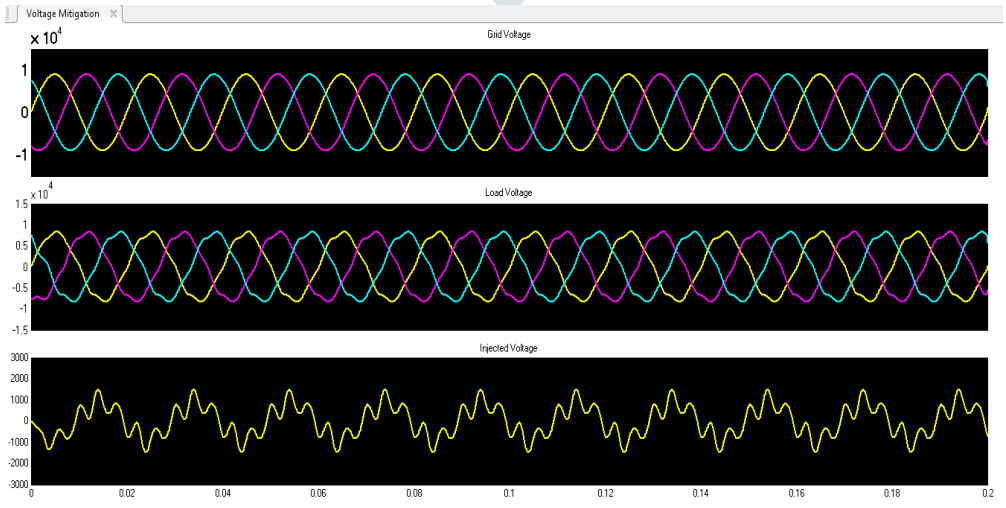

Fig 21: Input Voltage and Current from 11KV Source

Table 3: Comparison of Percentage Voltage THD of Various Controller of DVR

	With PI	With Fuzzy-PI	With KH-F
Voltage THD	8.81%	2.21%	0.08%

The table 3 shows the comparison of THD obtained from various techniques and it is clear from the table that the technique developed reduces the harmonics in SLV feeder line with DVR

3. Conclusion

The results obtained shows that the power quality issues at utility are considerably reduced using DSTATCOM and DVR which places an important role in eliminating the voltage fluctuations and sudden current surges that affect the consumer products. This is effectively achieved by using the novel control technique developed for DSTATCOM and DVR to compensate the reactive power developed in the grid i.e Krill herd fuzzy controller(KH-F) optimization discussed in this paper shows the effectiveness in eliminating the power quality issues .

4. ACKNOWLEDGMENTS

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