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ESRFT WITH ISCT FUNDAMENTAL EXTRACTOR THEORY BASED DVR CONTROLLER USED FOR POWER QUALITY IMPROVEMENT

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Abstract— *Most of the devices at present using in the automation industry are non-linear type and they are sensitive to voltage disturbances. Super computers, patient monitoring systems in hospitals and manufacturing industry desires balanced voltage continuously. But due to fault occurrence in the distribution network supply voltage will become unbalanced and hence connected load starts malfunctioning. To ensure the healthy working of the sensitive load devices during fault condition Flexible AC Transmission System (FACTS) equipment's are used in the transmission and distribution networks. In the FACTS family dynamic voltage restorer (DVR) is an important device used to control the power flow and provide protection of sensitive loads against voltage issues in the modern power system. In this paper, Instantaneous Symmetrical Component Theory (ISCT) based control process implemented to die out the electrical power quality difficulties like voltage sag/swell, transients, harmonics, interruption and distortion, from the supply voltage at the load bus. Extended Synchronous Reference Frame Theory (ESRFT) with ISCT based Controller uses the concept of positive sequence extraction to balance the phasors with the restoration of voltage and limit the third harmonic distortion (THD). In this case, extract positive sequence from voltage at PCC which then transformed to d-q components. Subsequently Controller performance the output is transformed back to a-b-c component known as reference signals and matched with real voltage signals at the load terminal or bus. PWM generator start working with difference of the signals as input excitation generate a sequence of six pulses through which functioning of IGBT based convertor can be controlled.*

Keywords — *Distribution system, DVR, ESRFT, FACTS, IGBT, ISCT, PCC, PLL, PWM, SRFT, VSI.*

I. INTRODUCTION

In recent times, considerably attention has been concentrated on the features of electrical power in the modern power distribution network. Power system quality represents the capability of electric energy provided from the power grid to the customers. Voltage disturbances takes place in the power system with the introduction of harmonics and voltage sags is extensively renowned as the serious matter which can disturbing power system stability. It can also affect both utility company as well as clients. Nonlinear devices produce harmonics which may affects end users devices [1]. IEEE Standard 1159-1995 describes voltage sags which is differences in voltage from 10% to 90% of rated voltage and range of time duration is few milliseconds to one minute [2-4] as shown in Figure 1. The chances of voltage sag occurrence at feeder closer to faulty feeder. Generally short circuits, single line to ground fault, lightning, sudden or unexpected applied access loads in the industry are the reasons of voltage sags and swells problems [5]. Voltage sags either symmetrical or unsymmetrical depends on the types of fault. If magnitude of the voltage phasors of all three phases are identical and phase angle between them is 120^0 after fault occurrence, the sag is named as symmetrical. If not, the sag is named as unsymmetrical. A triple line (L-L-L) short-circuits cause of symmetrical voltage drops. Due to lightning, bird accident with overhead transmission or distribution line and excitation of big transformers results in unsymmetrical fault comes in to picture [6]. A power controlling device is an equipment recommended to boost-up the power quality and supplied the improved power to a nonlinear electrical or electronics load named as dynamic voltage restorer[7- 10]. In other words, equipment that used to deliver healthy voltage of rated magnitude and provide the facility to utilize the sensitive devices. At the present time, voltage enhancer known as DVR used in distribution network which is generally utilized to solve the voltage issues [11- 13]. Whenever faults occurs in electrical power network voltage sag problem arises, at the same time DVR sense the disturbance and compensate the voltage within the shortest time period and feed the maintained voltage to the sensitive load as shown in Figure 2 to ensure the proper functioning of sensitive load [14, 17] .

DVR is a well-organized voltage source implanted between the distribution system and a sensitive load to enhancing the voltage level to remove troubles which can affect the functioning the complex load. DVR perform the functions such as compensation reactive power, removal of harmonics and limit the fault current. DVRs' controllers play a significant role to maintain the continuity, reliability, stability of the system and steady-state accuracy [15]. Now a days, a new software phaselocked loop (PLL) is recommended with the grouping of the benefits of techniques. It has a capability of fast phase-lock tracing and ensure complete mitigation of information oscillation of the discovery of control algorithm during abnormal state [16-17].Moreover, an innovative approach is proposed for the basic and the upper level unfair harmonic levels [18]. Hence such kind of schemes may increases the capability of the DVR to give the more accurate response. In spite of the appreciated growth added with innovative algorithms. These methods are principally committed to high and/or medium-voltage applications areas which required high rating dynamic voltage restorers with improved ability of controllers [19]. Design, modeling and simulation of a DVR carried out based on ESRFT with ISCT based Controller implement the concept of positive sequence extraction for voltage improvement using Simulink tool of MATLAB software is presented. Sim power system tool of MATLAB software used for research presented in this paper.

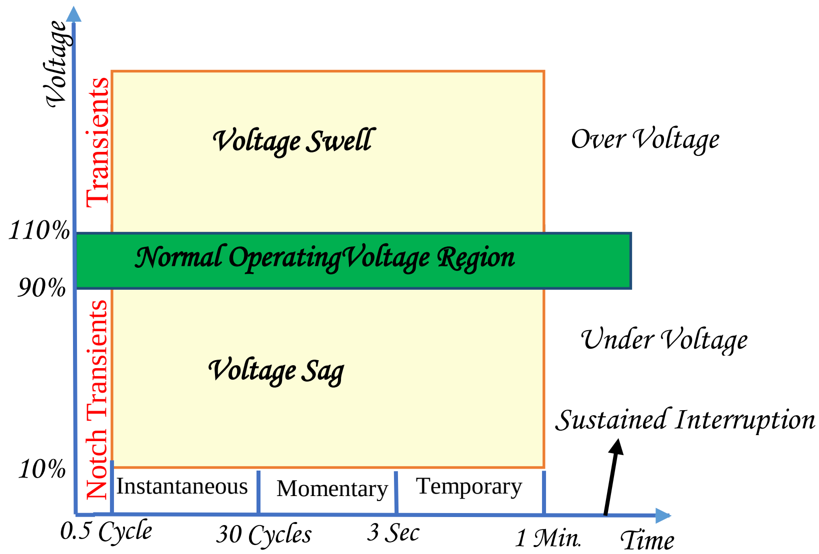

Fig.1. IEEE Standard 1159-1995 defines voltage sags and swell and other voltage difficulties during fault occurrence.

II. DESIGN OF DVR

Among several FACTS devices DVR is more robust, more accurate and more economic. It is used to ensure the functioning of sensitive load without affecting their performances. Figure 2 gives the location of in the distribution system of electrical network [17]. It is contains the following parts:

2.1 Energy storage unit

This is the backbone of DVR circuit which supplies electrical energy to the DVR for restoration of voltage during the fault in the power system. A DC capacitor or a battery utilized as an energy storing component.

2.2 Series Injection transformer

It is works like heart of DVR system injects the voltage received from the VSC and feed the maintained voltage to the non-linear loads in distribution system which is mandatory for the voltage restoration process [20]. In general injection transformer joined in series high voltage side with the distribution system even though it is linked to low voltage circuit of the DVR.

2.3 Voltage source converter

VSC is an important part of DVR. Basically it is power electronic configuration device. It is utilized to produce alternating voltage with the necessary phase angle, amplitude and frequency. Energy storage unit provides input to it [21].

2.4 Passive filters

A filter used in DVR circuit is the collection of passive elements like resistance, inductor, and a capacitor. It is implemented to decrease the unwanted harmonics and transients of the signal within the tolerable boundary which are produced by the converter [22]. Normally filter circuit designed to provide better sinusoidal waveform with least THD.

2.5 Bypass switch

This part of circuit plays an important role to cut off the DVR from the power system network against heavy currents during abnormal conditions.

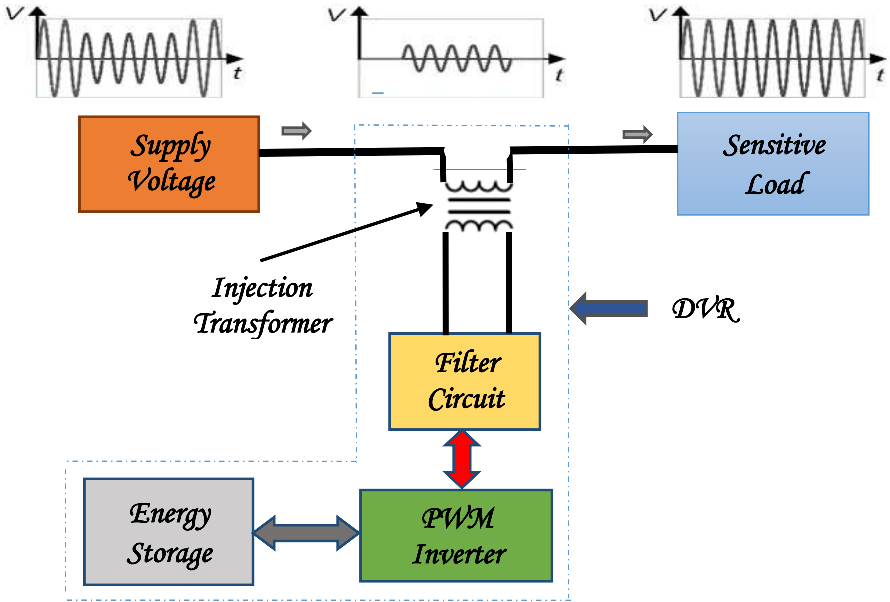

Fig. 2 Block diagram representation of Dynamic Voltage Restorer.

2.6 Control Unit

It is an important part of DVR and used to discover the existence of voltage difficulties of the power structure. Alternatively, it is acts as observer to check the voltage at the load-bus. Once voltage disturbances are observed then control part of DVR will be started to injecting the lost voltage after its magnitude and phase observation [23].

III. MATLAB BASED SIMULINK MODEL OF DYNAMIC VOLTAGE RESTORER

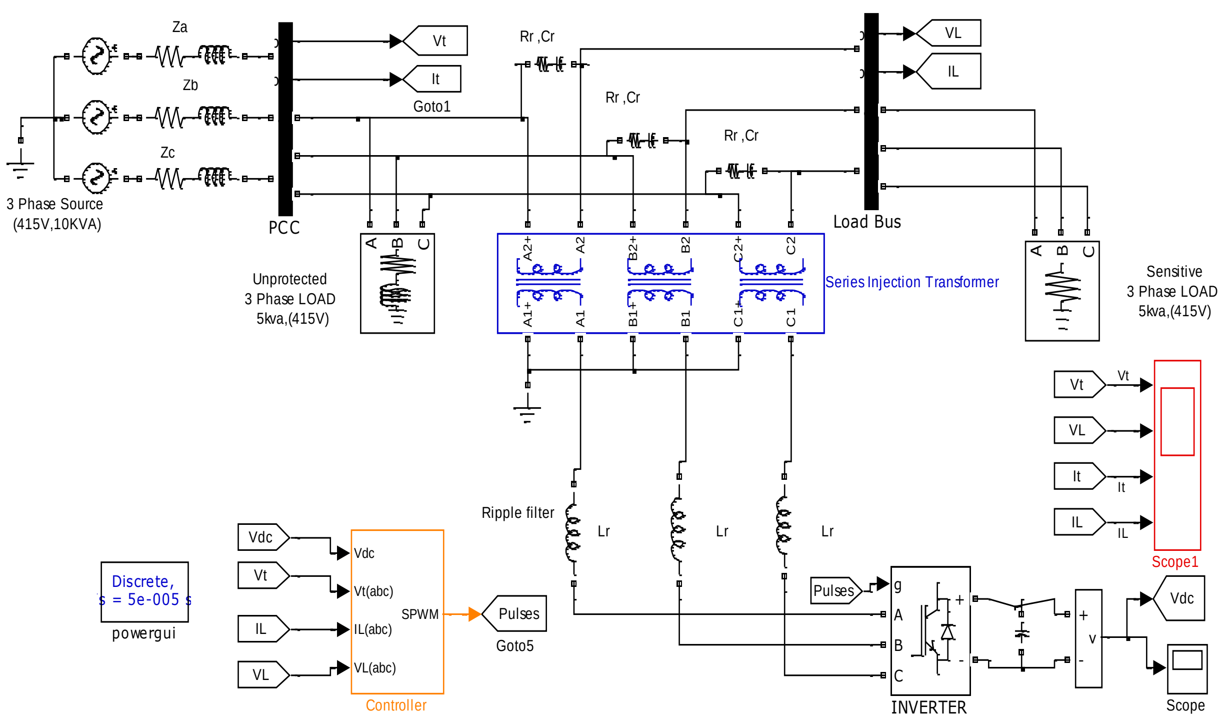

Fig.3. Simulink Model of DVR designed in sim power system tool.

The Simulink based DVR model is designed in three main parts like Distribution network, control circuit and inverter circuit. DVR connected between the supply lines and sensitive load through a series injection transformer.

IV. DVR CONTROL ALGORITHM

The controlling approach of DVR generates a 3-phase reference voltages and feed to the converter. The output of converter circuit is trying to retain the load voltage. Here DVR operation controlled by using dq0 transformation (Park's transformation). DVR controlling approach and block diagram with the inter connection of PLL is demonstrated in Figure 4. Ultimately, the PLL network creates an alternating signal waveform having zero degree phase difference with supply voltage [24]. If voltage difficulties come in to picture, an error will be generated and the PI controller compensates the lost voltage. The action of PI (proportional and integral) controller can be initiated by the error signal. A controller based on fundamental extractor theory utilized the idea of positive sequence extraction using ISCT. The 3-phase unstable systems described its steady state analysis by using symmetrical component method. The V_{a0}, V_{a1} and V_{a2} are shows the phasor presentation of zero, positive and negative sequence components of individual unbalanced phasors. The V_a, V_b and V_c are the phasors of supply voltage individually as shown in equation 1 and 2 respectively.

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha^2 & \alpha \\ 1 & \alpha & \alpha^2 \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \tag{2}$$

Where α is an operator which rotate the phasor by $+120^o$ without varying the magnitudeof the phasor upon which it operates. It has magnitude of unity and angle 120^o and is defined by

$$\alpha = 1\angle 120° = 1e^{\frac{j2\pi}{3}} = \cos\frac{2\pi}{3} + j\ \sin\frac{2\pi}{3} = -0.5 + j\ 0.866 \tag{3}$$

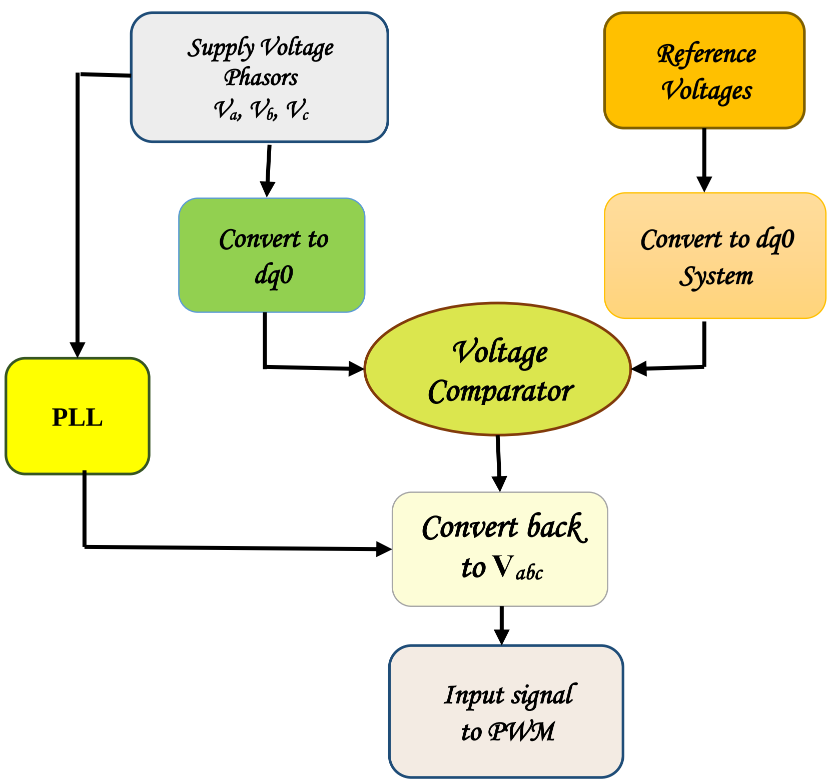

Fig.4SRFT based Control algorithm.

In this case positive sequence component extract from the PCC voltage (V_{PCC}) and transformed in to d-q component. Control part of the DVR circuit is given away in Figure 5 taken from Simulink model. After DVR Controller performance the d-q components converted in to a-b-c frame of voltages. Now these renewed values compared with reference signals. The differences of these two signals are given to pulse width modulation (PWM) generator [17, 20]. In the last stage PWM will provide a six pulses sequence which is utilized to govern the convertor based on insulated gate bipolar transistor (IGBT) [20-25] as shown in Figure 4.

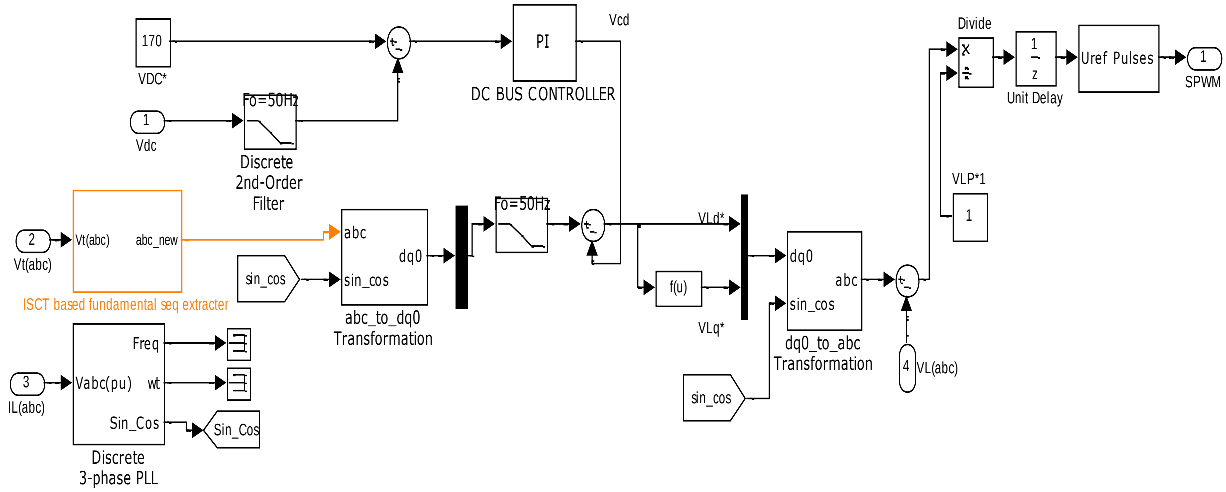

***Fig. 5 Extended SRFT with ISCT based DVR Controller*.**

V. RESULTS AND DISCUSSION

Case 1:

DVR simulation results documented when faults applied to balanced 3-phase balanced system. Which can be disturbed the synchronism of the load equipment's. All three phase voltages will be unbalanced having unequal magnitude and phase angle. First apply 3^{rd} order harmonics, 0.2 p.u. amplitude, -25^{0} phase displacement and zero sequence component. After that second first fault apply which contains 2^{nd} order harmonics,-0.2 p.u. amplitude, 35°phase displacement and negative sequence component. DVR simulation gives results which shows the distortion in phase-A only.

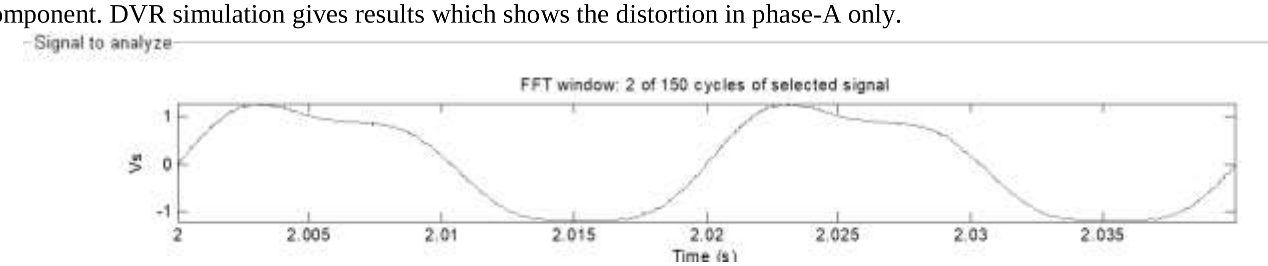

Fig.6. Voltage Wave form of Phase A at the point of common coupling (ESRFT, ISCT- FPS, Case-1)

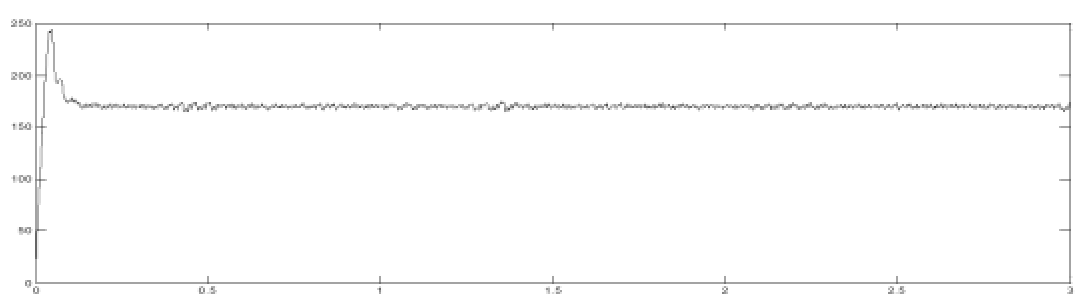

Fig. 7 DC Link Voltage Wave form at input of inverter (ESRFT, ISCT- FPS, Case-1).

DVR perform its action after comparison between supply voltage and reference voltage. DVR restore the voltage in all three phases. Phase A shown in simulation results for simplicity purpose only. It can be conclude that DVR compensate all 3-phases, reduce the THD and kept within permissible limit as well as ensure the proper functioning of sensitive load. The voltage waveform at PCC is shown in Figure 6. DC link voltage, Wave form of load voltage of phase-A and FFT analysis using ESRFT (ISCT- FPS) has shown in Figure 7 and 8 respectively. The controller of DVR based on ESRFT with ISCT perform in a dynamic way and remove the harmonics and transients with in the minimum time period. Supply Voltage contains 18.9% of THD. With the introduction of DVR total harmonic distortion (THD) decreases up to 2.91%. (avg) and bring back the voltage magnitude up to 0.998 p.u.(avg).

Load Voltage Wave form of Phase-A and FFT analysis using ESRFT (ISCT- FPS) are shown in Figure 7 and Figure 8 respectively. The DVR controller used in this Simulink model perform accurately and remove the harmonics. 18.9% of THD of main supply voltage is reduced up to 2.91%. (avg) and restore the magnitude up to 0.998 p.u. (avg) .

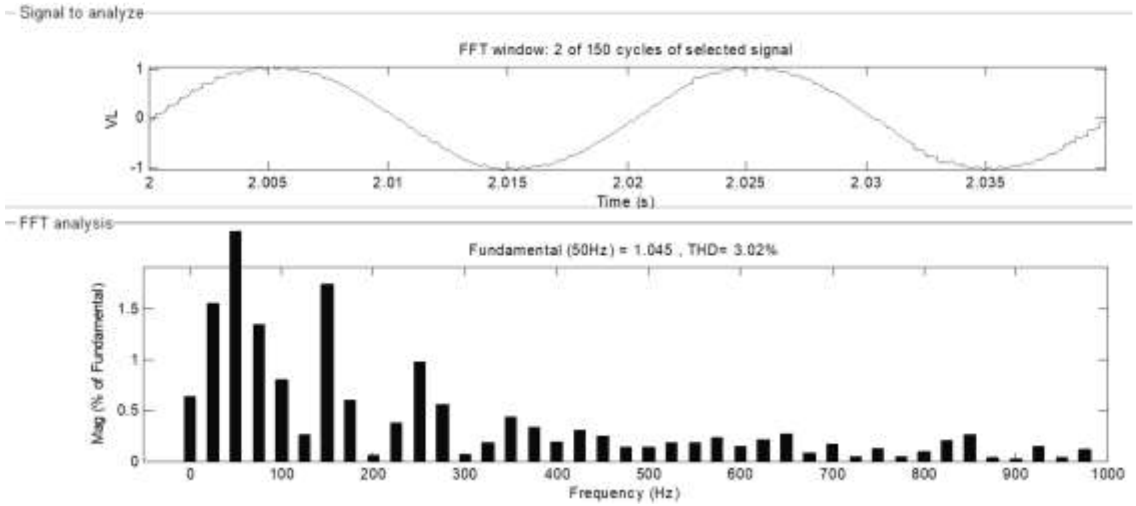

Fig. 8 Load Voltage Wave form of Phase-A & FFT analysis (ESRFT, ISCT- FPS, Case-1).

Case-2

In this case **t**wo types of disturbances were applied to a balanced 3-phase positive sequence voltage source that affects all three phases. DVR simulation results documented when faults applied to balanced 3-phase balanced system. Which disturb the synchronism of the load equipment's. All three phase voltages will be unbalanced having unequal magnitude and phase angle. First apply 1st order harmonics, 0.2 p.u. amplitude, -25^{0} phase jump and zero sequence component. The result of fault application can be observed in the form of unbalanced three phase voltages as shown in Figure 9. After that second type fault can be test which contains 1st order harmonics, 0.2 p.u. amplitude, 35° phase displacement and negative sequence component. DVR simulation gives results which shows the distortion in phase Phase-A only.DVR circuit sense the disturbances and restore the voltage in all three phases and make balanced as shown in Figure 10.

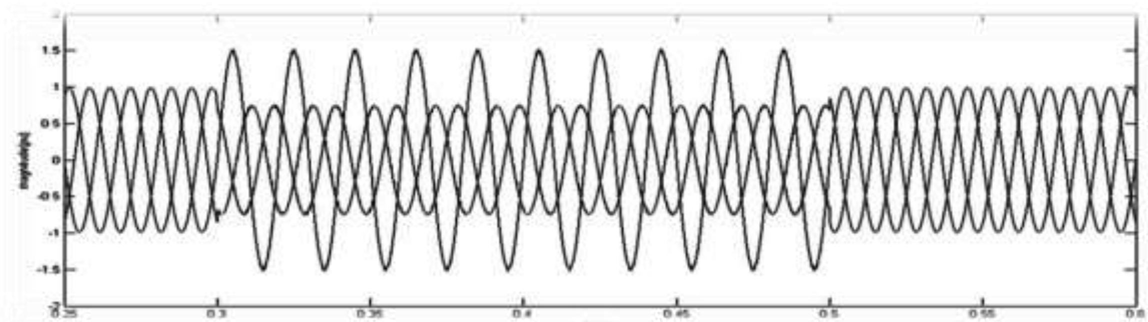

Fig.9.Graphical Representation of Voltage Wave form at PCC(ESRFT, ISCT- FPS,Case-2)

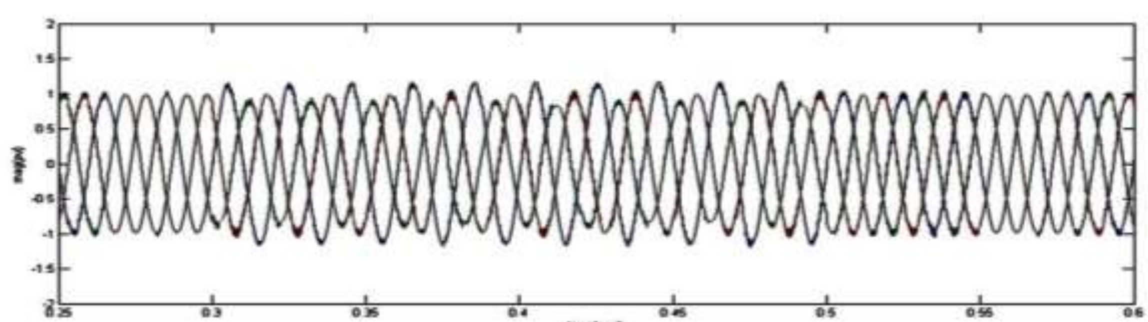

Fig.10. Graphical representation of voltage waveform at consumer end (ESRFT, ISCT- FPS,Case-2)

The DC link voltage and FFT analysis of case 2 are shown in Figure 11 and Figure 12 respectively. The voltage drop during fault event, distorted voltage, restored voltage and the level of THD recorded in Table 1.

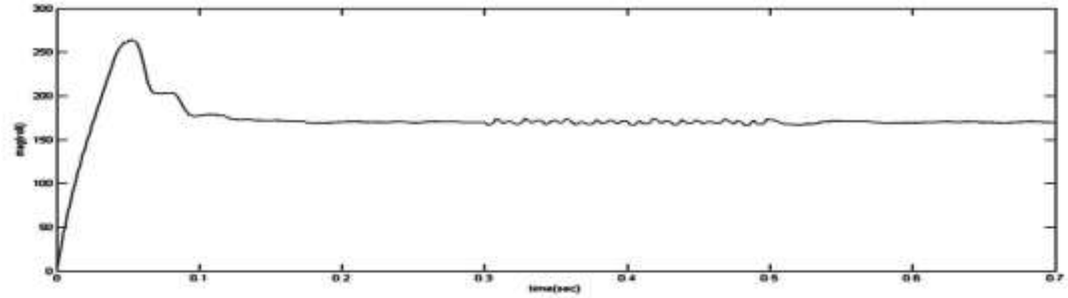

Fig. 11 Wave form of DC Link Voltage at input terminal of inverter (ESRFT, ISCT- FPS, Case-2).

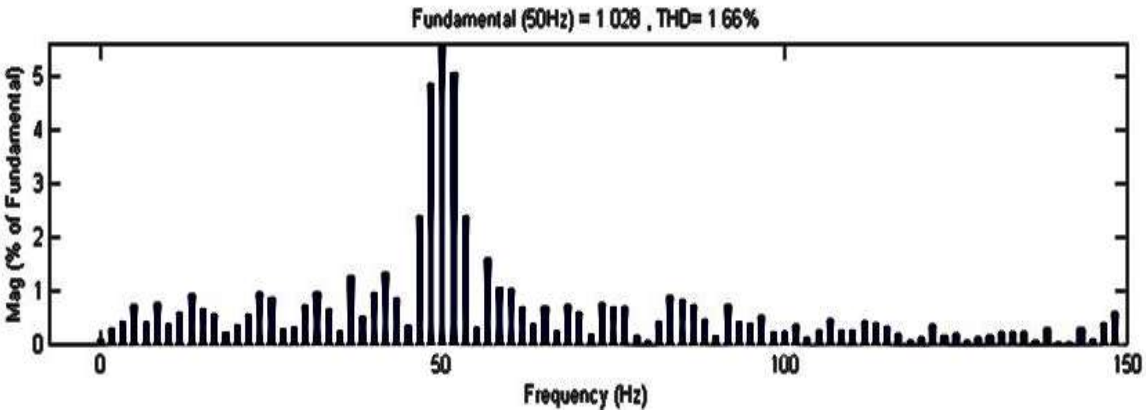

Fig. 12 FFT analysis of DVR simulation result (ESRFT, ISCT- FPS, Case-2).

TABLE: 1 DVR Simulation Result Summary (ESRFT, ISCT- FPS, CASE-2)

S.No.	**Phasor**	**Missing voltage Magnitude (p.u.)**	**Restored Voltage Magnitude (p.u.)**	**THD (%)**
1.	V_a	1.14	1.028	1.66
2.	V_b	0.92	0.9728	1.75
3.	V_c	0.90	0.986	2.02

Extended Synchronous Reference Frame Theory with Instantaneous Symmetrical Component Theory based control algorithm work satisfactorily and performed well for the removal of voltage problems. FFT analysis is a tool of MATLAB SIMULINK which shows the stable and maintained waveform of phase-A. Moreover DVR support to restore the voltage magnitude estimated as 0.995(avg.) and limit the THD up to 1.81% (avg).

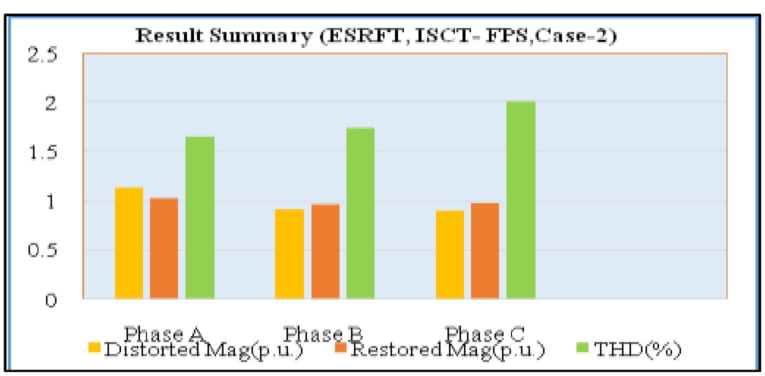

Fig.13 The response of the DVR in the bar code graph.

VI. CONCLUSION

ESRFT with ISCT based DVR controller gives the better simulation results comparatively. If two types of disturbances applied in balanced phase A, all three phases will become unbalanced. Hence 3 – phase system move towards unstable stage. In this situation ESRFT with ISCT control algorithm based DVR restore the missing voltage and after maintaining it feed to the sensitive load. The FFT analysis tool of MATLAB SIMULINK model gives the information of voltage restoration at the load terminal. DVR also reduced THD and kept within permissible limit. Hence this control scheme ensures the healthy operation of the sensitive load.

REFERENCES

[1] N.G. Hingorani, "Introducing Custom Power in IEEE Spectrum", 32p, pp 4l-48, 1995.

[2] Pychadathil, Jayaprakash, Bhim Singh, D. P. Kothari, Ambrish Chandra and Kamal Al-Haddad, "Control of Reduced-Rating Dynamic Voltage Restorer with a Battery Energy Storage System", IEEE Transactions on Industry Applications, Vol. 50, NO. 2, March/April 2014.

[3] Parag Kanjiya, Bhim Singh, Ambrish Chandra, and Kamal Al-Haddad, "SRF Theory Revisited to Control Self-Supported Dynamic Voltage Restorer (DVR) for Unbalanced and Nonlinear Loads" IEEE Transactions on industry Applications, vol. 49, No. 5, pp.2330-2340, Sept/Oct 2013.

[4] Jing Shi, Yuejin Tang, Kai Yang, Lei Chen, Li Ren, Jingdong Li, and Shijie Cheng, "SMES Based Dynamic Voltage Restorer for Voltage fluctuations Compensation" IEEE transactions on Applied Superconductivity. vol. 20, No. 3, pp.1360-1364. June 2010.

[5] P. Boonchiam, and N. Mithulananthan "Understanding of Dynamic Voltage Restorers through MATLAB Simulation" Thammasat I nt. J. Sc.Tech., Vol. 11, No. 3, pp. 1-6, July-September 2006.

[6] C. Benachaiba, and B. Ferdi "Voltage quality improvement using DVR", Electrical Power Quality and Utilization, Journal Vol. XIV,

[7] Mahmoud A. El-Gammal1, Amr Y. Abou-Ghazala, and Tarek I. El-Shennawy "Dynamic Voltage Restorer (DVR) For Voltage Sag Mitigation", International Journal of Electrical Engineering and Informatics, Volume 3, Number 1, 2011.

[8] Shazly A. Mohammed, Aurelio G. Cerrada, Abdel-Moamen M. A, And B. Hasanin" Dynamic Voltage Restorer (DVR) System For Compensation Of Voltage Sags", State-Of-The-Art Review, International Journal Of Computational Engineering Research (ijceronline.com), Vol. 3 Issue. 1, ISSN 2250-3005, Jan.2013.

[9] A. Visser, J. Enslin and H. Mouton, "Transformer-less Series Sag Compensation with a Cascaded Multilevel Inverter", IEEE Trans. Industrial Electronics, Vol. 49(4), pp. 824-831, Aug. 2002.

[10] P. Loh, M. Vilathgamuwa, S. Tang and H. Long, "Multilevel Dynamic Voltage Restorer", IEEE Power Electronics Letters, Vol. 2(4), pp. 125-130, Dec. 2004.

[11] P. Roncero-Sánchez, E. Acha, J. E. Ortega-Calderon Vicente Feliu, A. García-Cerrada, "A versatile control scheme for a dynamic voltage restorer for power-quality improvement", IEEE Trans., Power Del., vol. 24, no. 1, pp. 277-284, Jan. 2009.

[12] R. Omar, N. A. Rahim, and M. Sulaiman "New control technique applied in dynamic voltage restorer for voltage sag mitigation", American J. of Engineering and Applied Sciences 3 (1): pp.42-48, 2010.

[13] P. R. Sanchez, and E. Acha "Dynamic voltage restorer based on flying capacitor multilevel converters operated by repetitive control", IEEE Transactions on power delivery, Vol.24, No.2, pp. 951-960, April 2009.

[14] R. Amrita, and A. K. Nadir, "Modeling & Simulation of dynamic voltage restorer (DVR) for enhancing voltage sag", Sensors & Transducers Journal, Vol. 87, Issue 1, January 2008, pp. 85-93, 2008.

[15] Pradeep Kumar Bhardwaj and Dr. M. P Dave, "Design and simulation of self-supported DVR using SRFT," AKGEC International Journal of Technology, Vol. 5, No. 2, pp. 35-41, July-Dec 2014.

[16] Shakir, Pradeep Kumar Bhardwaj, Rambir and Tariq Nafees Khan," Solution of Power Quality Disturbances in Electrical Distribution Structure with the Introduction of Dynamic Voltage Restorer based on SRFT Control Algorithm", International Journal of Advance Engineering and Research Development, Volume 5, Issue 01, January-2018, e-ISSN: 2348 - 4470, print-ISSN: 2348-6406.

[17] Shakir, Pradeep Kumar Bhardwaj, Jyoti Ahlawat and Manish Sharma, "Electrical Power Quality upgradation with Dynamic Voltage Restorer based on ESRFT Control Algorithm", International Journal of Advance Engineering and Research Development, Volume 5, Issue 02, Febuary-2018, e-ISSN: 2348 - 4470, print-ISSN: 2348-6406.

[18] R. Amrita, and A. K. Nadir, "Modeling & Simulation of dynamic voltage restorer (DVR) for enhancing voltage sag", Sensors & Transducers Journal, Vol. 87, Issue 1, January 2008, pp. 85-93, 2008.

[19] Subhro Paul, Sujay Sarkar, Surojit Sarkar, Pradip Kumar Saha, Gautam Kumar Panda, "By Dynamic Voltage Restorerfor Power Quality Improvement", International Journal of Engineering and Computer Science ISSN: 2319-7242 Vol.2, pp. 234-239 Issue 1 Jan 2013.

[20] M. V. KasuniPerera, "Control of a dynamic voltage restorer to compensate single phase voltage sags" Master of Science Thesis, KTH Electrical Engineering, Stockholm, Sweden, 2007.
[21] Ray Arnold "Solutions to Power Quality Problems" power engineering journal pages: 65-73. 2001.
[22] T. Devaraju, V. C. Veera Reddy, and M. V. Kumar "Role of custom power devices in power quality enhancement: A Review", International Journal of Engineering Science and Technology, Vol.2 (8), pp. 3628-3634, 2010.
[23] R. Ibrahim, A. M. Haidar, M. Zahim, "The Effect of DVR Location for Enhancing Voltage Sag" Proceedings of the 9th WSEAS International Conference on Applications of Electrical Engineering, pp. 92-98.
[24] R. Omar, and N. A. Rahim, "Modeling and simulation for voltage sags/swells mitigation using dynamic voltage restorer (DVR)", Power Engineering Conference, 2008. AUPEC '08. pp. 1-5 Dec.2008.
[25] K. R. Padiyar, "FACTS controllers in power transmission and distribution", New Age International(P) limited , Publishers, New Delhi, 2007.