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Power Quality Enhancement using FACSRF-PLL DSTATCOM

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Abstract - This paper proposes a novel frequency adaptive cascaded synchronous reference frame-phase locked loop (FACSRF-PLL) based approach of load compensation for distribution static compensator (DSTATCOM). The non-linear and unbalanced load make the source current distorted. The CSRF-PLL can fine define fundamental angular frequency, amplitude & phase angle and positive sequence component. The FACSRF -PLL control approach provide switching pulses in a way to make source current balanced & sinusoidal and also improve power quality of system. Here FACSRF is act as a pre-filter for the PLL and improve performance under distorted grid conditions. The proposed FACSRF -PLL control approach is executed in MATLAB/ Simulink environment with various operating condition. The ability of the proposed approach has been related to the instantaneous PQ theory based control technique.

Index Terms: *Phase Locked Loop (PLL), Power Quality (PQ)*

INTRODUCTION

The commonly used synchronization tool for grid connected system is PLL which is used to synchronize various equipment in power system to the grid. Here SRF-PLL is mainly applicable to fine the positive sequence even in frequency adaptive system. It is applicable for both single and three phase power system. It can detect amplitude, fundamental frequency and phase angle in a faster way with more accuracy. But this SRF-PLL is prominent to system harmonics disturbances. To improve the act of SRF-PLL in structure having harmonics the bandwidth of it is reduced. By adjusting the bandwidth of SRF-PLL effect of harmonics and unbalance are greatly reduced which is cascaded SRF-PLL (CSRF-PLL). The CSRF-PLL can find fundamental angular frequency, amplitude & phase angle and positive sequence component.

The quality of power supply is critical at all levels of the power system, including distribution and transmission [1-4]. The non-linear loads at the consumer end pollute the supply by consuming non-sinusoidal current at the distribution level which may leads to malfunction of equipment at consumer side. Due to this nonlinear load the PQ issues like harmonics, unbalance & poor power factor arises in distribution system [5-8]. To improve the power quality where is active power filter were developed to operate at the distribution system. The DSTATCOM is used to improve PQ at the distribution level. Various control algorithms were developed for DSTATCOM to improve the PQ [9-16]. Here FACSRF-PLL based control methodology is applied for PQ improvement distribution level.

PROPOSED SYSTEM

The figure 1 shows structure of FACSRF-PLL based DSTATCOM with unbalanced load is linked with 3 phase supply. The DSTATCOM is connected to PCC & ripple filter which is used to reduce switching ripple and supplies the compensating current which improves PQ at PCC. The various components in DSTATCOM such as the DC bus capacitor and interface inductor can be designed using the following expressions

The DC capacitor reference voltage,

$$V_{dc} = \left(\frac{1}{C_{dc}}\right) \int i_{dc}\, dt \qquad (1)$$

The DC Bus Capacitor,

$$C_{dc} = \frac{\left(2X - \frac{X}{2}\right) nT}{(1.8Vm)^2 - (1.4Vm)^2} \qquad (2)$$

The Interface inductor,

$$L_f = \frac{1.6Vm}{4hF_{swmax}} \qquad (3)$$

Average load power (Pl),

$$P_l = \frac{1}{T}\int_{t_1-T}^{t_1} (V_{sa}i_{la} + V_{sb}i_{lb} + V_{sc}i_{lc})\,dt \quad (4)$$

$$P_{loss} = K_p e_{vdc} + K_i \int e_{vdc}\,dt \quad (5)$$

Error signal:

$$evdc = Vdcref - Vdc \quad (6)$$

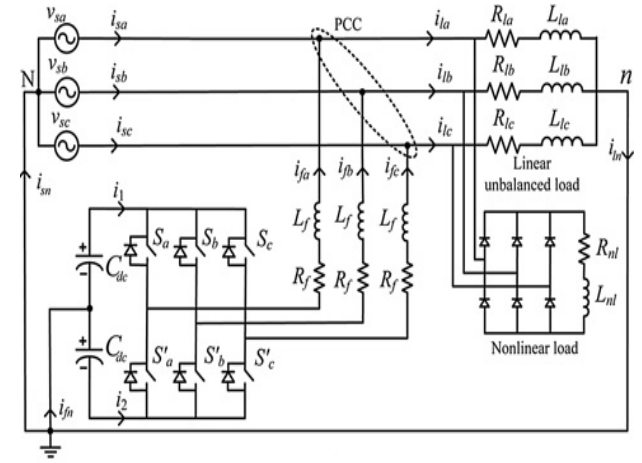


Figure 1: Structure of FACSRF-PLL based DSTATCOM of distribution system

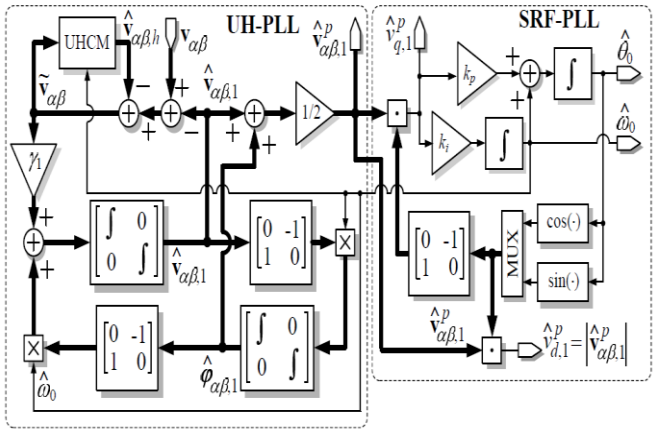


Figure 2: FACSRF-PLL based control approach

The proposed FACSRF-PLL based control technique to compensate the non-linear load & improves PQ of the distribution system is shown in figure 2. Here the switching pulses for the switches in VSI are developed by the proposed approach which is given to VSI switches.

The unit templates,

$$U_{pa} = \frac{V_a}{V_t}\ ;\ U_{pb} = \frac{V_b}{V_t}\ ;\ U_{pc} = \frac{V_c}{V_t} \quad (6)$$

$$V_t = \{\frac{2}{3}(V_a^2 + V_b^2 + V_c^2)\}^{1/2} \quad (7)$$

The DC voltage,

$$V_{dce}(t) = V_{dcref}(t) - V_{dc}(t) \quad (8)$$

$$W_L(t) = K_{pd}\{V_{dce}(t) - V_{dce}(t-1)\} + K_{id} * V_{dce}(t) + W_L(t-1) \quad (9)$$

$$Wqv(t) = K_{pd}\{V_{te}(t) - V_{te}(t-1)\} + K_{id} * V_{te}(t) + Wqv(t-1) \quad (10)$$

The reference currents are i^*_{sabcp} and i^*_{sabcq},

$$i^*_{sa} = i^*_{saq} + i^*_{sap}$$
$$i^*_{sb} = i^*_{sbq} + i^*_{sbp}$$
$$i^*_{sc} = i^*_{scq} + i^*_{scp} \quad (11)$$

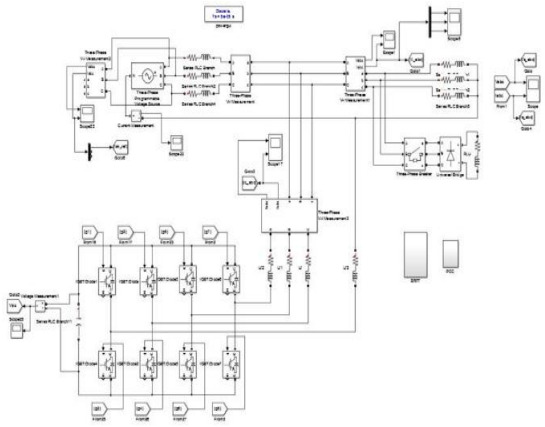


Figure 3 : Simulation of FACSRF-PLL DSTATCOM system

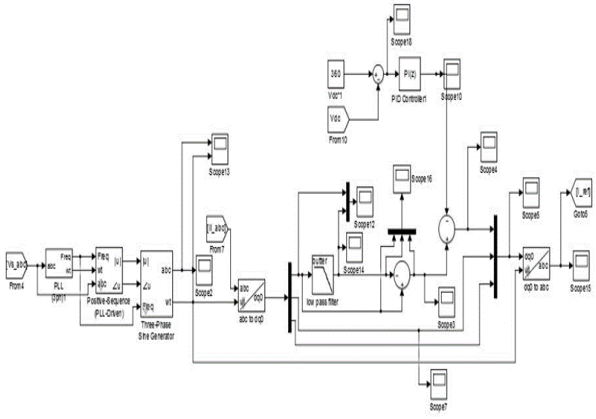


Figure 4: Simulation of FACSRF block

RESULTS AND DISCUSSION

The MATLAB/Simulink model of FACSRF- PLL DSTATCOM system is presented in figure 3&4. Here grid supplies 3 phase non-linear load. The voltage, current at load and source ends were measured then supplied to the FACSRF- PLL control approach to generate pulses for VSI.

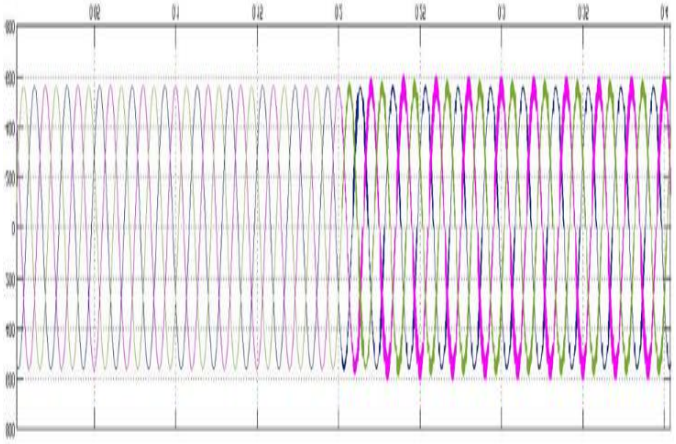


Figure 5 : Source voltage

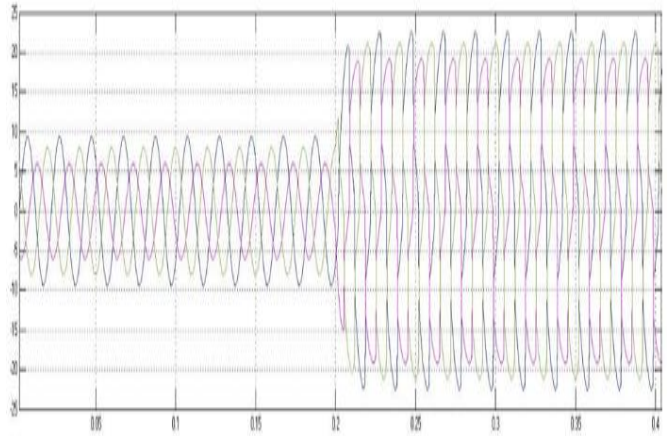


Figure 6 : Source current

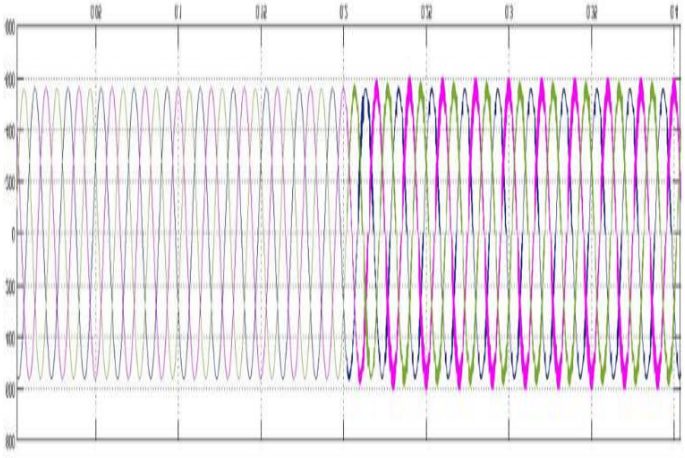


Figure 7 : Load voltage

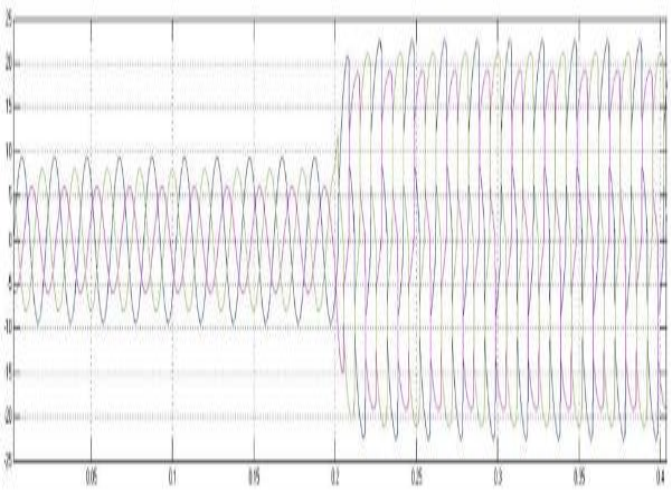


Figure 8 : Load current

The figures 5,6,7 & 8 show the source & load voltage & current waveforms before compensation of system

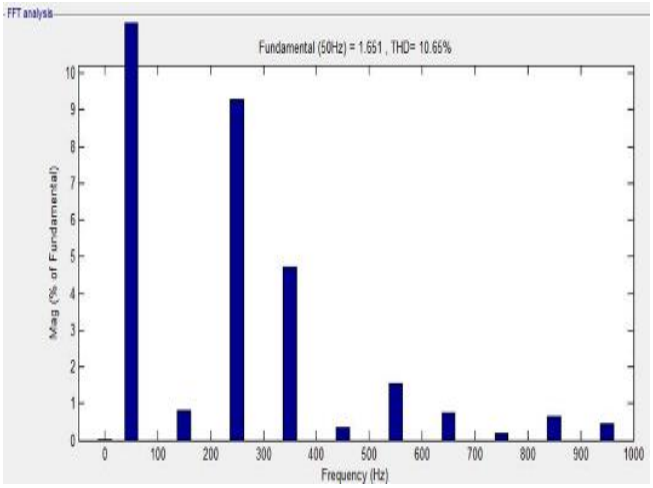


Figure 9 : THD - Load current

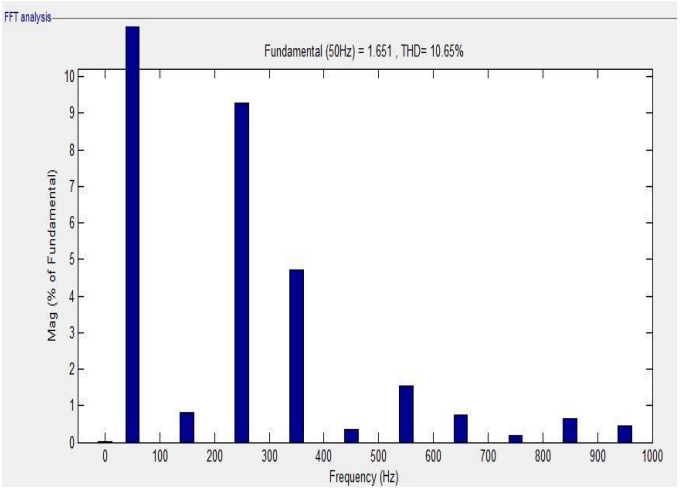


Figure 10 : Source current – THD without compensator

The figures 9,10,11 & 12 show the THD for load & source current and source voltage and figures 13 show the DC link voltage with FACSRF- PLL based DSTATCOM.

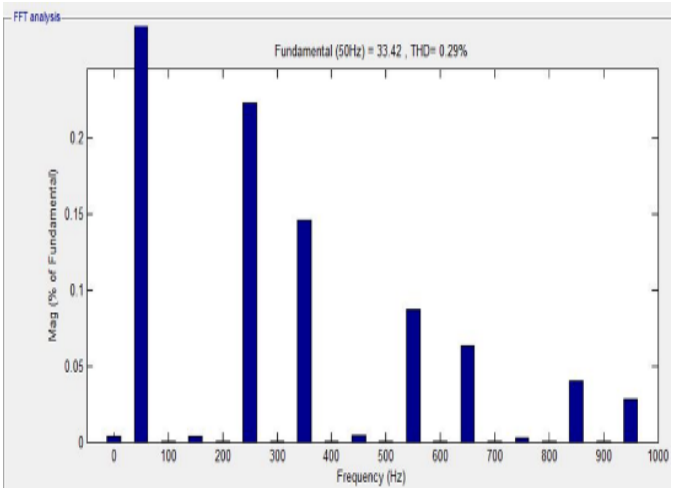


Figure 11 : Source current – THD with compensator

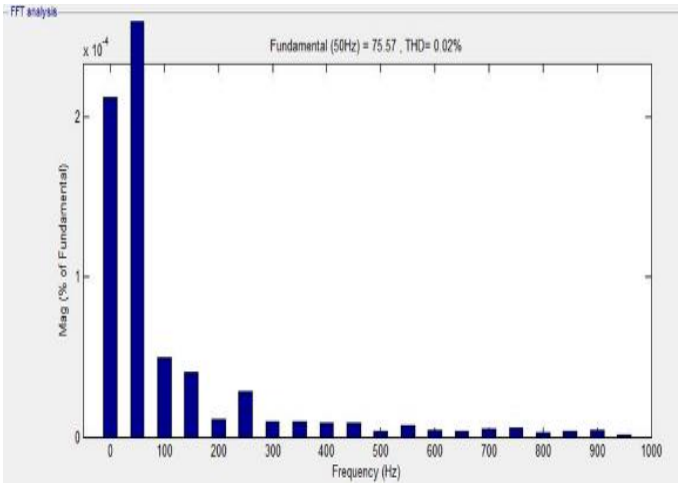


Figure 12 : Source voltage – THD with compensator

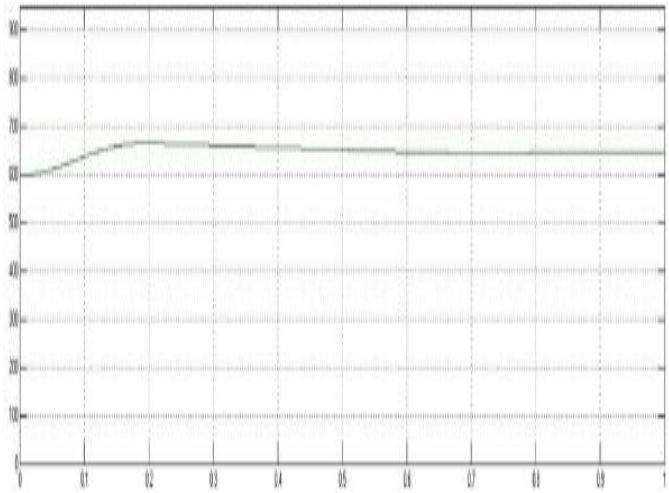
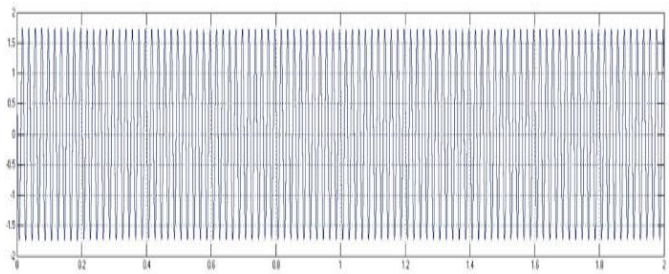


Figure 13 : DC link voltage



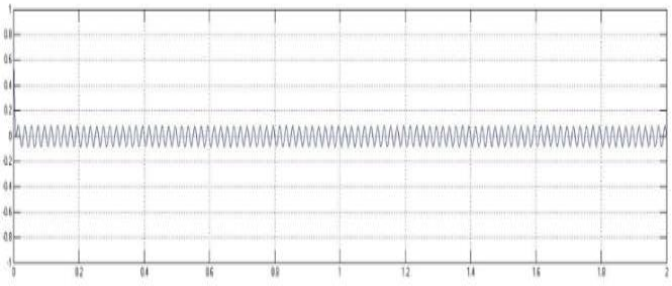


Figure 14 : Neutral currents

CONCLUSION

The proposed FACSRF-PLL based load compensation approach for DSTATCOM has been successfully implemented in distribution system with unbalanced and non-linear loads. The proposed FACSRF-PLL based control approach effectively compensate the loads by generating switching pulses for VSI even under polluted grid conditions. The proposed FACSRF -PLL control approach is simulated in MATLAB/ Simulink environment for various working conditions. The ability of the proposed approach has been related to the conventional control. The THD of source current without compensator is about 10.65%. The proposed FACSRF-PLL based DSTATCOM compensates and reduce source current THD to 0.29% which describes the activeness of the proposed controller in load compensation.

REFERENCES

[1] M. Badoni, A. Singh, and B. Singh, 'Variable forgetting factor recursive least square control algorithm for DSTATCOM', IEEE Trans. Power Del., vol. 30, no. 5, pp. 2353–2361, Oct. 2015.

[2] Bhim singh, 'Power quality and mitigation techniques', 1st edited in John wiley publisher, 2015.

[3] Arindam Ghosh, Gerard Ledwich, 'Power quality enhancement using custom power devices', Kluwer Academic Publishers, 2002.

[4] C Dugan, Mark F. McGranaghan, surya santoso, H. wayne Beaty , 'Electrical power systems quality', 2nd McGraw-Hill, 2004.

[5] Z.-Q. Wang, M. T. Manry, and J. L. Schiano, 'LMS learning algorithms: Misconceptions and new results on converence', IEEE Trans. Neural Netw., vol. 11, no. 1, pp. 47–56, Jan. 2000.

[6] N. Mohan, T. M. Undeland, and W. P. Robbins, 'Power Electronics: Converters, Applications, and Design'. New Delhi, India: Wiley, 2003.

[7] S. Mishra, 'Neural-network-based adaptive UPFC for improving transient stability performance of power system', IEEE Trans. Neural Netw.,vol. 17, no. 2, pp. 461–470, Mar. 2006.

[8] A. M. Munoz, 'Power Quality Mitigation Technologies in a Distributed Environment', Londn, U.K.: Springer, 2007.

[9] H. Akagi, E. H. Watanabe, and M. Aredes, 'Instantaneous Power Theory and Applications to Power

Conditioning'. New York, NY, USA: Wiley-IEEE Press, Jul. 2009.

[10] B. Chen, Y. Zhu, and J. Hu, 'Mean-square convergence analysis of ADALINE training with minimum error entropy criterion', IEEE Trans. Neural Netw., vol. 21, no. 7, pp. 1168–1179, Jul. 2010.

[11] B. Singh, S. S. Murthy, R. R. Chilipi, S. Madishetti, and G. Bhuvaneswari, 'Static synchronous compensator-variable frequency drive for voltage and frequency control of small-hydro driven self excited induction generators system', IET Generat., Transmiss. Distrib., vol. 8, no. 9, pp. 1528–1538, Sep. 2014.

[12] C. Kumar and M. K. Mishra, 'Operation and control of an improved performance interactive DSTATCOM', IEEE Trans. Ind. Electron., vol. 62,no. 10, pp. 6024–6034, Oct. 2015.

[13] Bhim singh, 'Application of LMS-Based NN Structure for Power Quality Enhancement in a Distribution Network Under Abnormal Conditions',vol 29, IEEE Trans. Neural Netw., May 2018 [14] M. Srinivas, I. Hussain, and B. Singh, 'Combined LMS-LMF based control algorithm of DSTATCOM for power quality enhancement in distribution system', IEEE Trans. Ind. Electron., vol. 63, no. 7, pp. 4160–4168, Jul. 2016.

[14] Kumar, C., Mishra, M.K.: 'Operation and control of an improved performance interactive DSTATCOM', IEEE Trans. Ind. Electron., 2015, 62, (10), pp. 6024–6034.

[15] Venkatraman, K., Selvan, M.P., Moorthi, S.: 'Predictive current control of distribution static compensator for load compensation in distribution system', IET Gener. Transm. Distrib., 2016, 10, (10), pp. 2410–2423.

[16] G Escobar etal.: 'Cascade three-phase PLL for unbalance and harmonic distortion operation (CSRF-PLL)', 40th Annual Conference of the IEEE Industrial Electronics Society, Dec. 2014.