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Planning of D-STATCOM for Improving Power Quality using ICCT with the Assistance of PI and Hysteresis Controllers

Virendra Jain[1], Virendra S. Solanki[2], R.P. Kumawat[3]
[1, 2, 3]Deptt. of Electrical & Electronics Engg., MIT Mandsaur-458001 (M.P.), India

Abstract: This work shows a technique equipped for structuring D-STATCOM to decrease consonant bending and right the power factor to improve power quality. The D-STATCOM with Indirect control Theory feeds a wide assortment of load. The exhibition of the system is simulated for linear, non-linear load. Simulation results justify enhanced power quality of the system with D-STATCOM application.
Keywords: Programmable Source, DSATACOM, Capacitive filter, Power Quality, PI & Hysteresis controller.

I. INTRODUCTION

The Distribution Static synchronous Compensator (D-STATCOM) is a main member from the FACTS group of intensity electronic based controllers. It has been considered for a long time, and is presumably the most generally utilized FACTS gadget in the present power system. The D-STATCOM voltage and reactive power compensation are generally related through the magnetic of the D-STATCOM.

This traditional power flow model of the D-STATCOM dismisses the effect of the high frequency impacts and the switching characteristics of the power electronics on the active power losses and the reactive power injection (absorption).

The D-STATCOM has risen as a confident device to offer for voltage sag decrease as well as for a large group of other power quality arrangements, for example, stabilization, flicker suppression, power factor correction, and harmonic control. D-STATCOM is a shunt device that creates a balanced 3-ϕ voltage or current with capacity to control the extent and the phase angle. For the most part, the D-STATCOM design comprises of a run of the typical 12- pulse inverter arrangement of action, a dc vitality stockpiling device; a coupling transformer connected in shunt with AC system, and associated control circuits. The setups that are extra refined use multi pulse as well as staggered designs.

The VSC changes over the dc voltage over the storage device into a lot of three-phase AC O/P voltages. By controlling the firing angle of VSC, the reactive power can be produced from or consumed by STATCOM and the voltage regulation can be cultivated.

The simulation results demonstrate the improvement in current control reaction. These strategies are tried in MATLAB, and their outcomes are acquired.

II. SYSTEM ARRANGEMENT

A Distribution static compensator (D-STATCOM) is electronic based devices which power quality in electrical distribution system. It relies upon a power devices voltage source converter and can go about as either a source or sink of reactive AC capacity to a power arrange in fig .1 exhibits a separated system with D-STATCOM set up on it. A programmable voltage source is used in the system.

D-STATCOM in shunt setup go about as a wellspring of leading or lagging VARS associated with change the voltage at the point of common coupling (PCC). Right when the heap of client end isn't actually the predictable power made by the non linear load, the additional power sucked up by D-STATCOM however when the heap is overpower the need of customer end of non linear load capacity, D-STATCOM furthermore goes about as source of power. D-STATCOM supplies the required reactive pieces of the supply current and besides holding voltage at PCC terminals similarly as harmonics compensation. Fig.1 shows the block diagram of system with D-STATCOM.

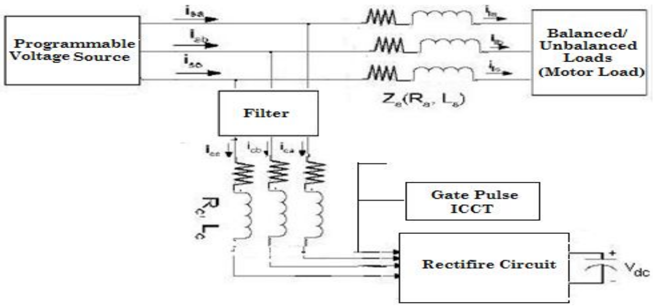

Fig. 1: Block Diagram of D-STATCOM

III. CONTROL SCHEME

The configuration of D-STATCOM as shown in Fig. 1 consists of the DC link; hence the DC link voltage remains practically constant. A DC link capacitor (C1) is also connected as shown. The values of the parameters for capacitor and controller are mentioned in Parameter list. The block diagram for the control scheme of D-STATCOM is shown in Fig.2. It utilizes one proportional-integral (PI) controller for regulating the ac terminal voltage. The In-phase components of the D-STATCOM reference currents are required for charging the dc capacitor to the level of reference dc bus voltage and to meet its losses. The amplitude of in-phase component of the reference supply currents (I_{spdr}) is kept constant at a particular value depending on actual power necessary of the load. The instantaneous values for in-phase components of supply reference currents are obtained by multiplying I_{spdr} with the in-phase unit current vectors (u_a, u_b, u_c) derived from three phase sensed terminal voltages ne PI controller is applied over the sensed and reference ac mains voltage. Its output is considered as the amplitude of quadrature component of the supply reference currents (I_{spqr}). The instantaneous values are obtained by multiplying the output of this PI controller with the quadrature unit current vectors (w_a, w_b, w_c) derived from unit in-phase current vectors (u_a, u_b, u_c) which are calculated from three-phase sensed terminal voltages. The total reference supply currents are obtained by adding respective in-phase and quadrature components.

PWM based hysteresis current controller is employed over instantaneous reference supply currents and sensed supply currents. If i_{sa} < (i_{sar}-h_b), the upper switch is turned 'OFF' and lower switch is turned 'ON'. If i_{sa} > (i_{sar}+h_b), the upper switch is turned 'ON' and lower switch is turned 'OFF'. In this manner, the switching logic for other two phases is obtained and the controller is able to regulate the currents in a band around the desired reference value.

IV. MATHEMATICAL MODELING OF D-STATCOM

3-Ø reference supply currents are calculated using 3-Ø supply voltages. These reference supply currents consist of two components, one in-phase and another in quadrature with the supply voltages.

A. In-Phase Components of Reference Supply Current's Calculation

The amplitude of in-phase component of reference supply currents (I_{spdr}) is kept fixed at a specific value so that D-STATCOM supplies fixed real power. Three-phase in-phase components of the reference supply currents are calculated using the in-phase unit current vectors (u_a, u_b,u_c) derived from 3-Ø terminal voltage (V_a, V_b, V_c) using the following equations.

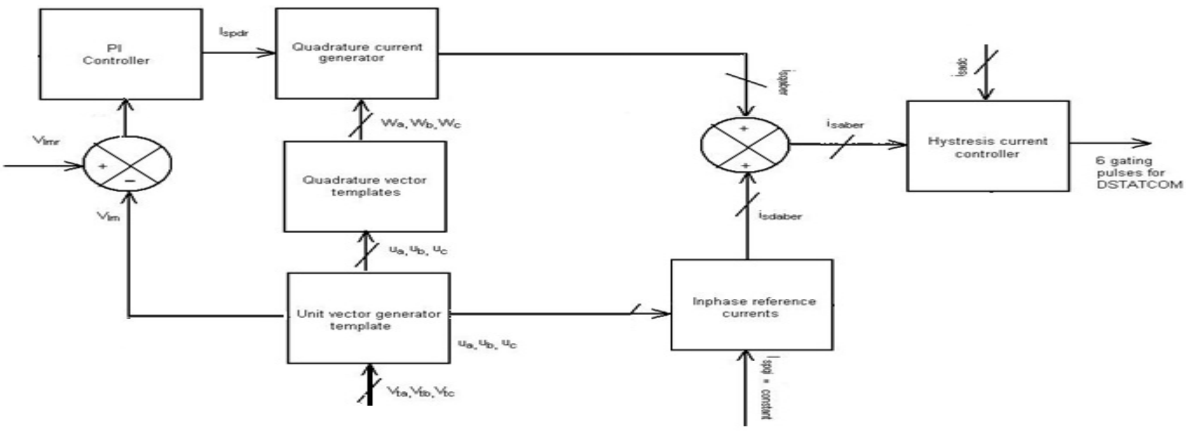

Fig. 2: Control Scheme of DSTATCOM

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$u_a = V_{ta}/V_{tmn}$
$u_b = V_{tb}/V_{tmn}$
$u_c = V_{tc}/V_{tmn}$ (1)

The amplitude of the supply voltage (V_{tmn}) is computed as:

$V_{tmn} = \sqrt{2/3}\,(V^2_{ta} + V^2_{tb} + V^2_{tc})$ (2)

The amplitude of in-phase component of reference supply currents is calculated as:

$I_{sadr} = I_{spdr} * u_a$

$I_{sbdr} = I_{spdr} * u_b$

$I_{scdr} = I_{spdr} * u_c$ (3)

B. Quadrature Components of Reference Supply Current's calculation:-

The amplitude of quadrature component of reference supply currents is computed using a PI controller over the average value of amplitude of supply voltage (V_{tm}) and its reference counterpart (V_{tmr}).

$I_{spqr} = I_{spqr(n-1)} + K_{pq}\{V_{ae(n)} - V_{ae(n-1)}\} + K_{iq}\, V_{ae(n)}$ (4)

Where $V_{ae(n)} = V_{tmr} - V_{tm(n)}$ denotes the error in V_{tmn} calculated over reference V_{tm} and average value of voltage of V_{tm}. K_{pq} and K_{iq} are the proportional and integral gains of the PI controller.

The quadrature unit current vectors are derived from in-phase unit current vectors as:

$W_a = (-u_b + u_c)/\sqrt{3}$
$W_b = (u_a\sqrt{3} + u_b - u_c)/ 2\sqrt{3}$
$W_c = (-u_a\sqrt{3} + u_b - u_c)/ 2\sqrt{3}$ (5)

3-Ø quadrature components of the reference supply currents (i_{saqr}, i_{sbqr}, i_{scqr}) are computed using their amplitude and quadrature unit currents vectors as:

$i_{saqr} = I_{spdr} * W_a$

$i_{sbqr} = I_{spdr} * W_b$

$i_{scqr} = I_{spdr} * W_c$ (6)

C. Total Reference Supply Current's Calculation

Three phase instantaneous reference supply currents are computed by adding in-phase and quadrature components expressed as:

$i_{sar} = i_{sadr} + i_{saqr}$

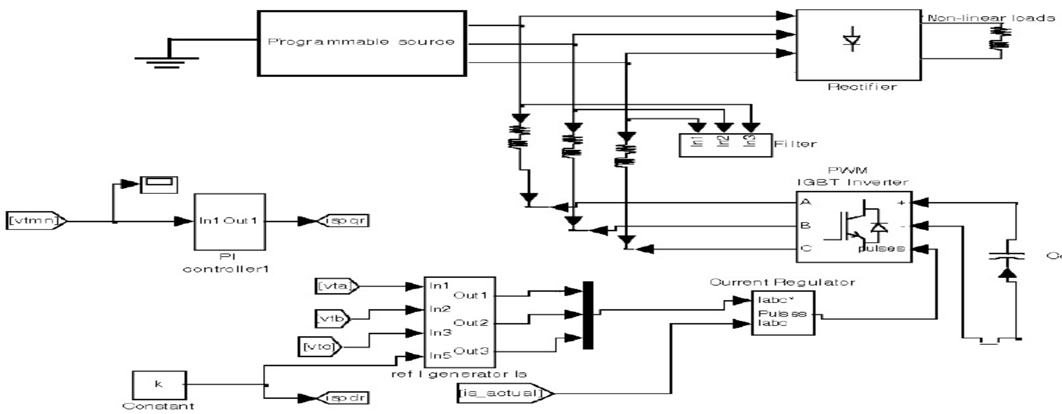

Fig. 3: MIATLAB based model of DSTATCOM system with Non-Linear Load

$i_{sbr} = i_{sbdr} + i_{sbqr}$
$i_{scr} = i_{scdr} + i_{scqr}$ (7)

A hysteresis current controller is employed over the reference and sensed supply currents to generate gating pulse of IGBT's of the D-STATCOM. This gives appropriate gating signals for all the three lags of VSI.

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V. MATLAB BASED CIRCUITRY OF D-STATCOM

This section illustrates the model of D-STATCOM along with programmable voltage source. A programmable supply is feeding in to the variety of loads is show in fig 3 (a) and 3 (b). The PI controller is tuned to regulate the ac terminal voltage at the PCC. The power as well as control circuit are molded in Matlab / Simulink and fig 3 (a) (b) shows the Simulink diagram of D-STATCOM and the load of the distribution system. A small capacitor filter is connected to the PCC.

The D-STATCOM configuration has a voltage source inverter molded using universal bridge from PSB toolbox library. It uses IGBTs each shunted by a reverse parallel connected fast switching freewheeling diode. The Linear and Non-Linear loads are connected to the output of the system. The linear load on the system is represented by 3-ϕ resistive-inductive (R-L load) for lagging power factor. Switches are suitably connected for constructing the load either balanced or unbalanced. The Non-linear load connected is represented in the form resistive load connected across a 3-Ø diode rectifier. In the D-STATCOM system controller block basically contains several subsystems like measurement system, reference current generation, ac voltage regulation loop, PI controller and hysteresis current controller. Fig 3(a) shows the simulink Circuitry of D-STATCOM with Linear Loads and fig 3 (b) shows the Circuitry of D-STATCOM with Non-Linear Loads

A. Hysteresis Controller

Hysteresis controller is utilized freely for each phase and directly produces the switching signals for the switches of the inverter. The error signal is the distinction between the reference current and the actual current. In the event that the error current exceeds the furthest reaches of the Hysteresis band, the upper switch of the inverter arm is killed and the lower switch is turn ON. On the off chance that the error current crosses the lower furthest reaches of the Hysteresis band, the lower switch is turn OFF and the upper switch is turned ON.

VI. RESULTS & ANALYSIS OF LINEAR AND NONLINEAR LOAD

A. Linear Load Result Descussion

Show characteristics of the D-STATCOM system of Linear load are given in Fig. 5 (a), (b), (c), (d), (e) shows variation of source current (I_s), Triggering pulse, Compensation current (I_c), I_s harmonics spectrum and I_l harmonics spectrum. The required parameters of the system are given in PARAMETER. According to uncompensated line harmonics of Source current (I_s) is 46% and load current (I_l) is 57%. According to IEEE rules harmonics should be less than 5%. In this paper Linear load THD of Source current (I_s) is 0.01% and load current (I_l) is 0.01%.

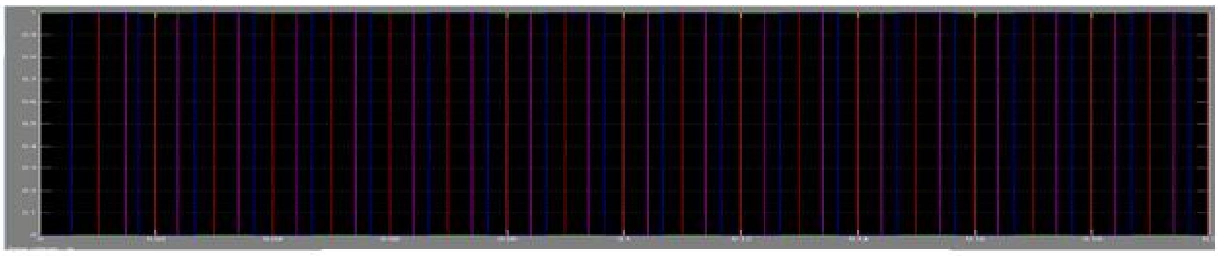

Fig.5 (b) Triggering pulse waveform

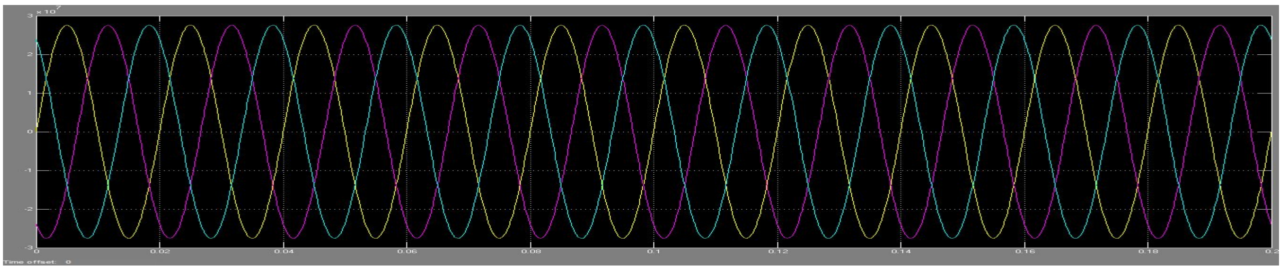

Fig. 5 (a) Source current waveform

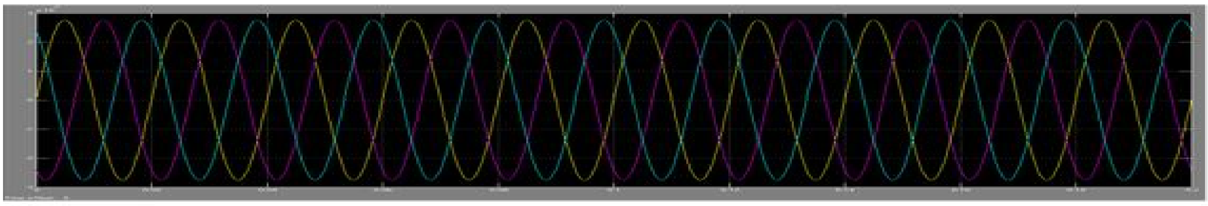

Fig.5 (c) Compensation current waveform

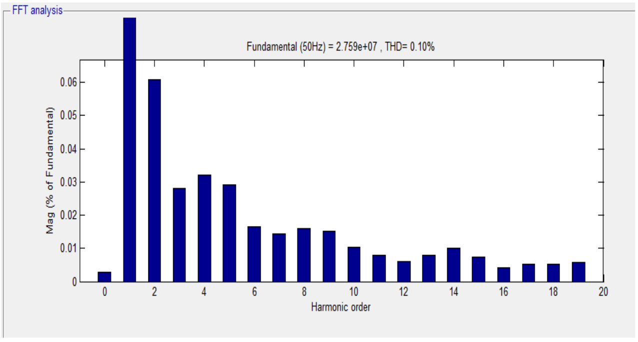

Fig.5 (d) I_s harmonics spectrum

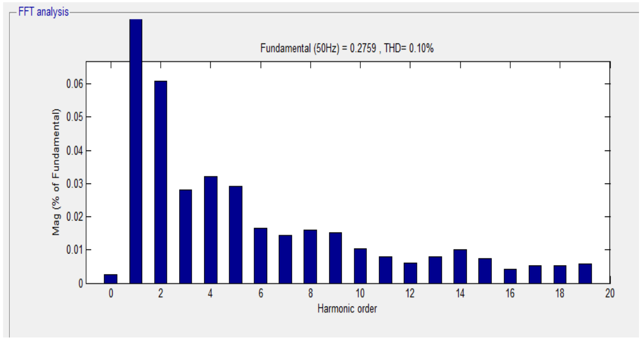

Fig.5 (e) I_l harmonics spectrum

B. Nonlinear Load Result Descussion

Show characteristics of the D-STATCOM system of Non-Linear load are given in Fig. 6(a), (b), (c), (d), (e) and (d) shows variation of source current (I_s), Load current (I_l), Gate pulse, I_s harmonics spectrum, I_l harmonics spectrum, I_c harmonics spectrum. The required parameters of the system are given in PARAMETER. In my result analysis nonlinear compensated THD is 0.07%.

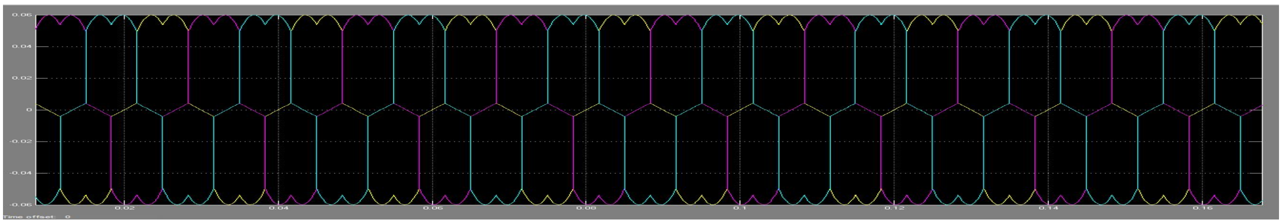

Fig. 6 (a) Source current waveform

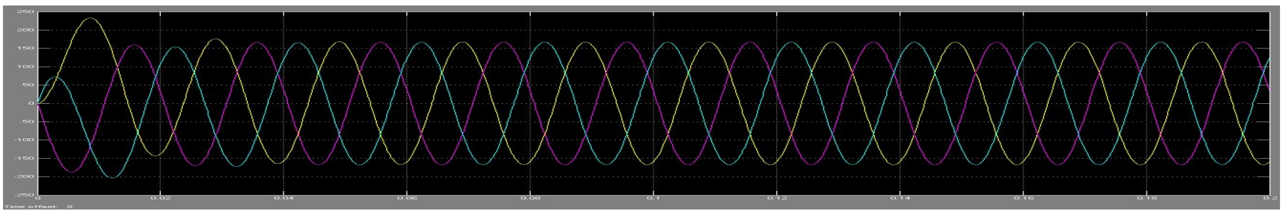

Fig.6 (b) Load current waveform

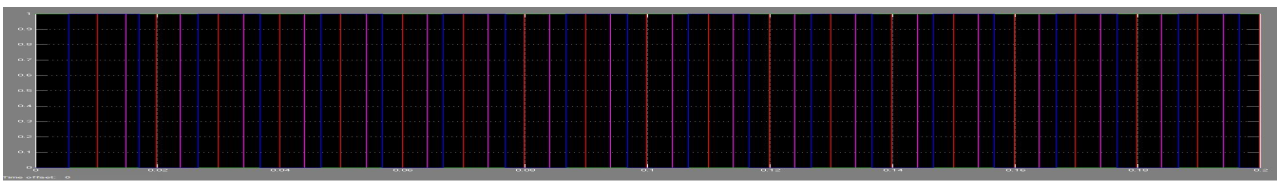

Fig.6 (c) Gate Pulse waveform

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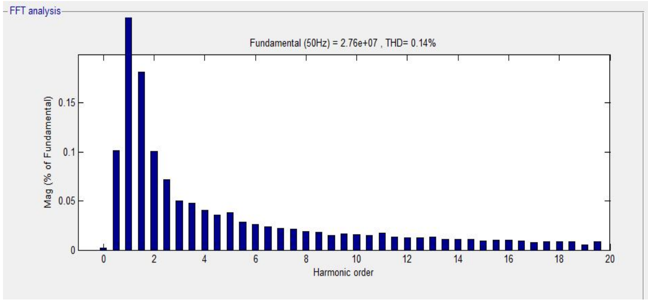

Fig.6 (d) I_s harmonics spectrum

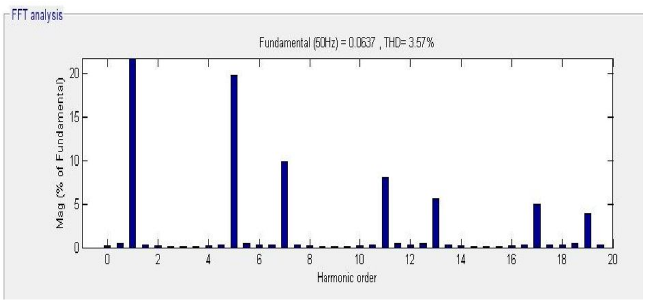

Fig.6 (e) I_l harmonics spectrum

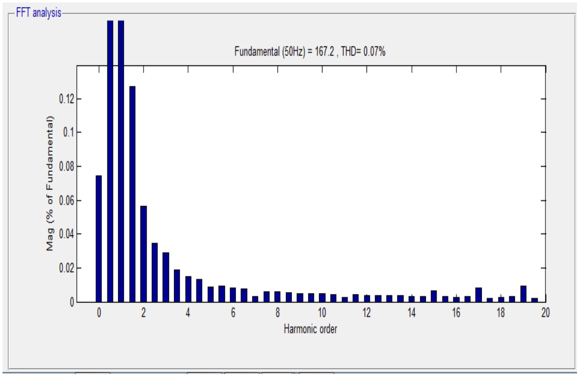

Fig. 6(f) I_c harmonics spectrum

VII. CONCLUSION

In recent years, along with the rapid increasing electric power requirement, the reconstruction of India urban and rural power network is more and more urgent. There will be huge demand for reactive power compensation to improve the efficiency and stability of AC transmission systems during transmission upgrade process. This paper introduces STATCOM technologies, and gives a description of its Control theory and to improve power quality with the reduction of Harmonics in the transmission line. When the reactive power will be minimized power factor also be improved as per the IEEE. As one of the second generation FACTS devices, STATCOM should be given more attention for long-term consideration. D-STATCOM is able to reduce harmonics in voltage at PCC and supply currents to less than 5% IEEE 519 standards. BESS reduces harmonics in supply current to a large extent and provides quality power. It is found that D-STATCOM is able to provide more benefits in terms of improved voltage, the results from digital simulation show good dynamic performances of D-STATCOM in power system voltage regulation.

VIII. PARAMETERS

L_c= 5mH, R_c = 0.1Ω, h_b=0.5A, C_1=5000F, R_l = 1000 Ω, P = 0.43, I = 0.15, D = 0.

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