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OPERATION AND CONTROL OF AN IMPROVED PERFORMANCE INTERACTIVE DSTATCOM

P.Vijayabaskarasst Prof Mahabarathi Engineering College, Chinnasalem, Villupuram Dist. Pvbaskar84@Gmail.Com

R.V.Jananimahabarathi Engineering College, Chinnasalem, Villupuram Dist. Rvjvala92@Gmail.Com

ABSTRACT: ***The improved performance interactive distribution static compensator (DSTATCOM) to address limitations of conventional current control mode (CCM) and voltage control mode (VCM). The proposed scheme provides smooth transfer of modes of operations. In normal operation, the DSTATCOM operates in CCM to make sources current balanced, sinusoidal and at unity power factor. If there is any voltage disturbance, the CCM operation cannot improve load voltage. So it will changed to VCM which maintains a constant voltage across sensitive loads. This interactive DSTATCOM ensures continuous, flexible, and robust operation of the load. The filter current requirements also will reduce the losses in filter and feeder, improves inverter efficiency, and requires reduced inverter for sag mitigation. Deadbeat predictive control algorithm for CCM as well as VCM operation are developed for fast operation during mode transfers. The performance of the proposed scheme is validated by simulations are done with MATLAB/SIMULINK and the results are exhibited.***

IndexTerms—*Voltage control mode, current control mode,power factor.*

1 INTRODUCTION

Switching devices in combination with unbalanced reactive loads produce current related power quality (PQ) problems by making source currents distorted and unbalanced. A distribution static compensator (DSTATCOM) operating in current control mode (CCM) is used to mitigate current related PQ problems. In CCM operation, the DSTATCOM supplies reactive and harmonic component of load currents to make source currents balanced, sinusoidal, and in-phase with respective phase load voltages. Generally, faults in power system and energisation of larger loads create voltage disturbances like sag and swell. Also, integration of intermittent distributed generation causes voltage fluctuations in the distribution system. These voltage disturbances significantly affect the power transfer from the source to load and degrade the performance of sensitive loads. However, conventional CCM operation of DSTATCOM cannot improve the load voltage. This is major limitation ofCCM operation of DSTATCOM which considerably restricts its utilization.

A DSTATCOM, when operated in voltage control mode(VCM), is one of the most effective device used for load voltage regulation. In VCM operation, the DSTATCOM regulates load voltage at a constant reference value by supplying appropriate fundamental reactive current into the source. Therefore, VCM operation of DSTATCOM provides stable and continuous operation of the load. However, conventional VCM operation of DSTATCOM maintains an arbitrary chosen voltage of 1.0 p.u. at the load terminal. For this voltage at load terminal, source exchanges reactive power even at normal operating conditions. This continuous reactive power exchange results in more reactive current flow in the voltage source inverter (VSI) as well as feeder. Consequently, losses in the VSI and feeder increase. Therefore, VCM operation of

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DSTATCOM is not required during normal supply conditions.

Aforementioned analysis brings the fact that the conventional CCM and VCM operations of DSTATCOM are notrequired during voltage disturbances and normal disturbances,respectively. This greatly limits utilization of the DSTATCOM. Moreover, recent advancements in device topologies and control algorithms have encouraged customers to look for devices which can provide various operational characteristics with less number of components, reduced cost, weight, and space. A possible solution to improve utilization of DSTATCOM is to operate the device in different modes during normal operation and voltage disturbances. However, feasibility and advantages of interactive DSTATCOM operation, where it has capability to transfer modes of operation while remaining connected to the distribution system has not been explored in the literature.

This paper proposes operation and control of an improvedperformance interactive DSTATCOM for continuous and stable load operation while addressing aforementioned issues. In this work, a control algorithm is proposed to compute range of source voltage within which a DSTATCOM should operate in CCM. This algorithm depends upon the supply voltage, maximum and minimum feeder impedance, and load current. Outside this range, operational mode of DSTATCOM is transferred to VCM. This interactive DSTATCOM provides several operational features which are not possible in conventional DSTATCOM operation i.e., 1) Advantages of CCM during normal supply conditions, 2) Advantages of VCM during voltage disturbances, 3) Unlike conventional VCM, no reactive power exchanges with the supply during normal supply conditions, 4) Reduced losses in VSI and feeder compared to conventional VCM, and 5) Requires reduced rating VSI for sag mitigation compared to conventional VCM.

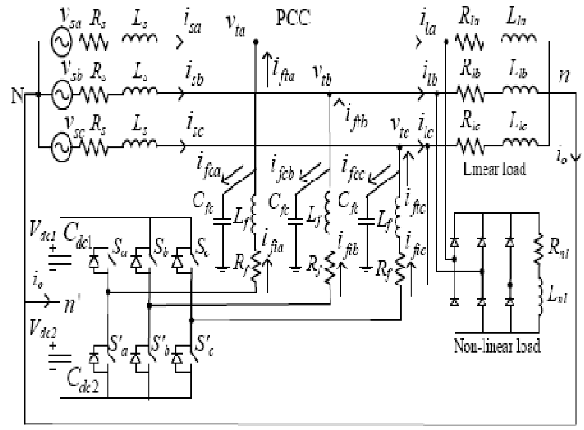

Fig 1.Three phase circuit of DSTATCOM in distributed system.

Deadbeat predictive control algorithms for CCM as well as VCM operation are developed for fast operation during mode transfers.

2 CONTROLLER DESIGN IN CCM AND VCM

The DSTATCOM remains operational without taking anyreal power from the source. However, dc link voltage decreasescontinuously due to the losses in the inverter. Therefore, a control loop is required to maintain the capacitor voltage at a reference value by compensating its losses. It is achieved by taking small real power from the source. The capacitor voltage control in CCM and VCM is achieved as following.

1) Control of dc Link Voltage in CCM:

Let the totallosses in the VSI be represented by$P_{LOSS.}$These losses must be supplied by the source for keeping dc link voltage constant. These are computed using a proportional-integral (PI) controller at positive zero crossing of phase-a voltage. It helps in maintaining the dc link voltage($V_{DC1}+V_{DC2)}$ at a predefined reference value ($2v_{dcref}$) by drawing a set of balanced currents from the source and is given as

$$P_{loss} = K_{pc}\, e_{vdc} + K_{ic} \int e_{vdc}\, dt$$

Are proportional gain, integral gain, and voltage error of the PI controller, respectively.

2) Control of dc Link Voltage in VCM:

Average real powerat the PCC (Ppcc) is sum of average load power (Plavg)and VSI losses (Ploss). The power, Ppcc, is taken from the source depending

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upon the angle between source and load voltages i.e., load angle _. The VSI losses are compensated by taking small real power, Ploss, from the source. If capacitor voltage is regulated to a reference value, then in steady state condition Ploss is a constant value and forms a fraction of Ppcc. Thus, δ is also a constant value. Once operation mode of DSTATCOM is transferred to VCM, dc link voltage is regulated by generating a suitable value of δ The total dc link voltage (vdc1 + vdc2) is compared with a reference voltage and error is passed through a PI controller. Output of the PI controller, δ, is given as

$$\delta = K_{pv}\, e_{vdc} + K_{iv} \int e_{vdc}\, dt$$

where Kpv and Kiv are proportional and integral gains of the PI controller, respectively. For stable operation, the value of δ must lie from 0 to 90 degree. Consequently, controller gains are quite small and are chosen carefully.

3 PROPOSED SCHEMES

AC source block and linear load block are the main power transmission areas. Statcom Switches which convert DC current to AC current is connected to the power line. The conversion of AC to DC is performed by PWM pluses which are given by the controller.

Generally, loads perform satisfactorily within the 10%range of the nominal voltage (i.e., 0.9 to 1.1 p.u.),

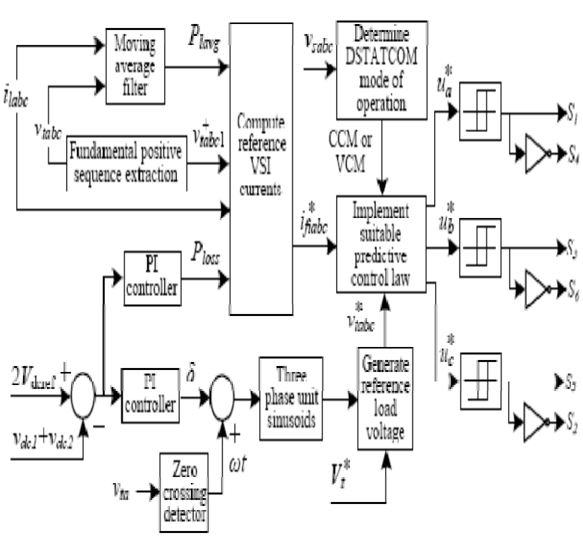

Fig 3.1 Control block diagram of interactive DSTATCOM.

are also called normal operating conditions. In these conditions, currentrelated PQ problems are of the main concern. Therefore,the DSTATCOM is operated in CCM for load harmonicand reactive current compensation. It results in balanced and sinusoidal source currents with unity power factor at the PCC. However, the load voltage can change at any time due to voltage disturbances. This will result in performance deterioration of the sensitive loads making CCM operation of DSTATCOM redundant. In this case, DSTATCOM must switch to VCM from CCM to protect sensitive loads from these unwanted variations in voltage by maintaining a constant voltage at the load terminal. In this section, a control algorithm for flexible mode transfer between CCM to VCM and vice versa has been presented.Several schemes have been presented to estimate source voltage for different applications like grid connected inverters, rectifier operation, motor drive application, renewable energy applications, power quality control, etc.,.The source voltage measurement schemes used in above applications are equally applicable for DSTATCOM application as well. Therefore,
it is assumed that the measurement of source voltage is available. Based on (28) and (29), a source voltage range is derived for CCM operation of the DSTATCOM. Any voltage deviation from this range is an indication of the voltage disturbance and the DSTATCOM mode will be transferred to VCM.load voltage is 0.9748 p.u. for a source voltage of 1.0 p.u. under the worst normal operating conditions. The voltage sag refers to reduction in load voltage from 0.9 to 0.1 p.u. of nominal value for half cycle to one minute It means that if Vs is 0.9232 p.u. then PCC will experience sag. Thus, it is possible to set limit for sag occurrence as Vs = 0.9232 p.u. and is denoted as lower limit. A swell is defined as increase in terminal voltage from 1.1 to 1.8 p.u. From nominal voltage for half cycle to one minute. From (29), Vs = 1.1 p.u. will produce a swell at PCC at worst normal operating condition and is denoted by upper limit. Thus, it can be concluded that:
(1) If Vs is less than 0.9232 p.u. and greater than 1.1 p.u. then the DSTATCOM can operate in VCM to regulate load voltage.
(2) If source voltage lies between 0.9232 to 1.1 p.u. then the DSTATCOM can operate in CCM.

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4 SIMULATION RESULTS

This chapter illustrates the results obtained using the computer programs. The proposed system is simulated using MATLAB/Simulink. MATLAB is one of the most successful software packages currently available. It is a powerful, comprehensive and user friendly software package for simulation studies. A very nice feature of Simulink is that it visually represents the simulation process by using simulation block diagram. Especially, functions are then interconnected to form a Simulink block diagram that defines the system structure. Once the system structure is defined, parameters are entered in the individual subsystem blocks that correspond to the given system data. Some additional simulation parameter must also be set to govern how the computation is carried out and the output data will be displayed.

Nominal source voltageis applied for t = 0 to 0.4 s. The DSTATCOM operates in CCM to compensate for load harmonic and reactive current. The load voltage and source current are sinusoidal. The filter current, consisting of harmonic and reactive components of load current, makes the load voltage and source current in phase with each other. Also, source does not exchange reactive power as opposed to 4 kVAr in conventional VCM operation. Further, a voltage sag of 30% is created for 10 cycles from t = 0.4 to 0.6 s. Once sag is detected, the mode of operation is changed to VCM and a constant voltage of 0.9 p.u. is maintained at the load terminal. The source current increases during this period due to reactive current supplied by the filterfor providing voltage support.

However, the reactive power supplied by the filter is only 18 kVAr as compared to 27 kVAr in conventional VCM operation. At t = 0.6 s, source voltage is brought back to normal value. Hence, the operational mode of the DSTATCOM is transferred to CCM. The voltage at the dc bus, shown in Fig. 6(g), is maintained at 1200 V during the CCM using the PI controller. During sag, the voltage decreases but PI controller used in VCM slowly brings it back towards the reference value. Once sag vanishes, the CCM PI controllerbrings the voltage to the reference voltage.

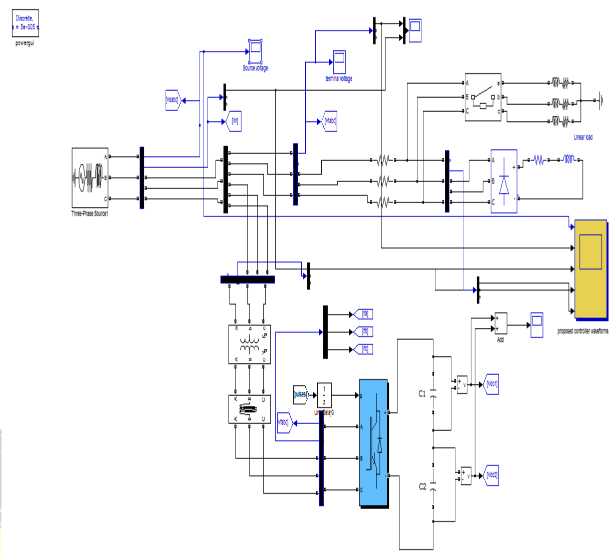

Fig 4.1 simulation circuit

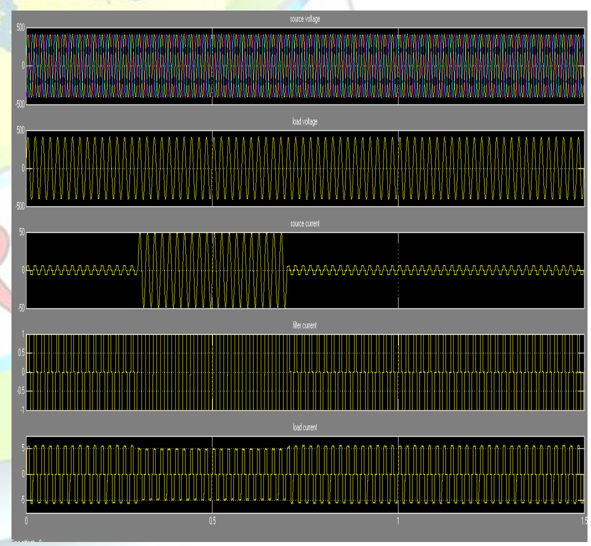

Fig 4.2 simulation result in proposed scheme during normal to sag

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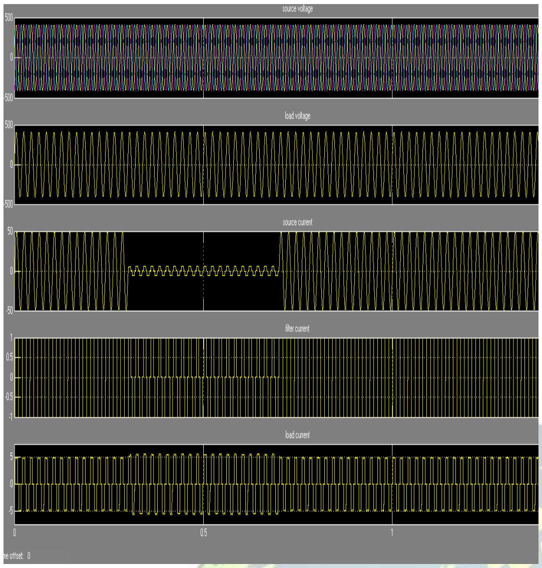

Fig 4.3 simulation result in proposed scheme during normal to swell.

5 CONCLUSIONS

In this project, the simple control algorithm proposed here, defines a range of supply voltage for which DSTATCOM operates in CCM to mitigate current related PQ problems. During voltage disturbances, operational mode of the DSTATCOM is transferred into VCM from CCM to protect sensitive loads. The scheme ensures continuous operation of the load. Moreover, losses in feeder and VSI are reduced which improves efficiency of the system. Additionally, these advantages are achieved using a reduced power rating VSI. Therefore, the proposed interactive DSTATCOM has improved performance with reduced loss, cost, and power rating VSI as compared to the conventional CCM and VCM DSTATCOM operation. The simulation confirm the effectiveness of the proposed scheme.

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