International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 2 Issue 3 ǁ March. 2013 ǁ PP.12-17

Design Strategy for Optimum Rating Selection of Interline D-STATCOM

G.Muralikrishnan[1], Dr. C. Sharmeela[2]

[1](*Asst. Professor, Department of E.E.E, P.B. College of Engineering, India*)
[2](*Asst. Professor, Department of Chemical Engg, A.C.Tech Campus, Anna University, India*)

ABSTRACT: *This paper is concerning about calculating the optimum rating for two D-STATCOMs when used in the interline mode i.e. Interline D-STATCOM (ID-STATCOM) Structure. An ID-STATCOM will consist of two or more D-STATCOMs which have a Common dc link and thus will exchange active power. This will increase the compensation range of an ID-STATCOM compared with separate similar D-STATCOMs. The limitations of ID-STATCOM operation in terms of active power exchange will be explained and based on that, the expressions governing the steady state operation of ID-STATCOM will be derived. The Compensation range of an ID-STATCOM is compared with that of two separate D-STATCOMs. This paper will also explain how the limitations in absorbing power from a healthy feeder will narrow the compensation range of an ID-STATCOM. In the proposed approach, all possible scenarios concerning healthy and faulty feeders will be taken in to consideration.*

Keywords - *Common DC-link, ID-STATCOM, PCC, PWM technique, VSC.*

I. INTRODUCTION

Voltage variations are one of the major power quality (PQ) events that can cause substantial damage to consumers with sensitive loads [1]. These disturbances are normally caused by system faults, load variations, energization of large loads and poorly designed systems. Traditional methods of combating voltage variations include tap-changing transformers, constant voltage transformers and uninterruptible power supplies. Nowadays in advance, custom power devices such as static transfer switches (STS), Distribution-STATCOM or D-STATCOM, unified power quality conditioner (UPQC) and dynamic voltage restorers (DVRs) are some emerging solutions to mitigate the damaging consequences of voltage variations [2].

D-STATCOM (Distribution Static Compensator) is a shunt device which is generally used to solve power quality problems in distribution systems. D-STATCOM is a shunt device used in correcting power factor, maintaining constant distribution voltage and mitigating harmonics in a distribution network. DSTATCOM is a voltage-source inverter (VSI) based shunt device generally used in distribution system to improve power quality. The main advantage of DSTATCOM is that, it has a very sophisticated power electronics based control which can efficiently regulate the current injection into the distribution feeder or bus. The second advantage is that, it has multifarious applications, e.g. i. Cancelling the effect of poor load power factor. ii. Suppressing the effect of harmonic content in load currents. iii. Regulating the voltage of distribution bus against sag/swell etc., compensating the reactive power requirement of the load and so on.

II. D-STATCOM

A DSTATCOM is a controlled reactive source, which includes a Voltage Source Converter (VSC) and a DC link capacitor connected in shunt through Coupling Transformer, capable of generating and/or absorbing reactive power. The operating principles of a DSTATCOM are based on the exact equivalence of the conventional rotating synchronous compensator. A DSTATCOM is a controlled reactive source, which includes a Voltage Source Converter (VSC) and a DC link capacitor connected in shunt, capable of generating and/or absorbing reactive power. The AC terminals of the VSC are connected to the Point of Common Coupling (PCC) through an inductance, which could be a filter inductance or the leakage inductance of the coupling transformer, as shown in Fig. 1.

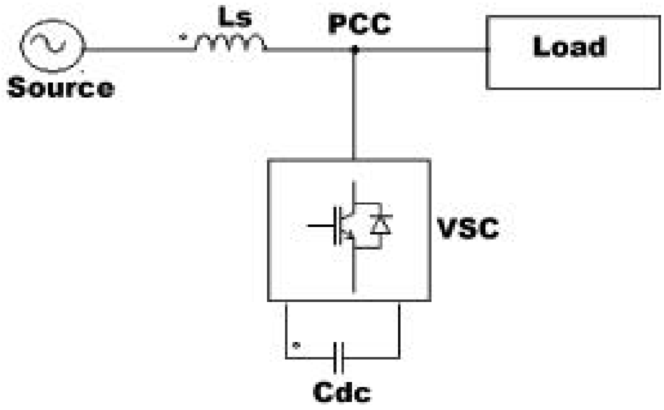

Figure 1: Basic structure of D-STATCOM

The DC side of the converter is connected to a DC capacitor, which carries the input ripple current of the converter and is the main reactive energy storage element. This capacitor could be charged by a battery source, or could be recharged by the converter itself [3]. If the output voltage of the VSC is equal to the AC terminal voltage, no reactive power is delivered to the system. If the output voltage is greater than the AC terminal voltage, the DSTATCOM is in the capacitive mode of operation and vice versa. The quantity of reactive power flow is proportional to the difference in the two voltages.

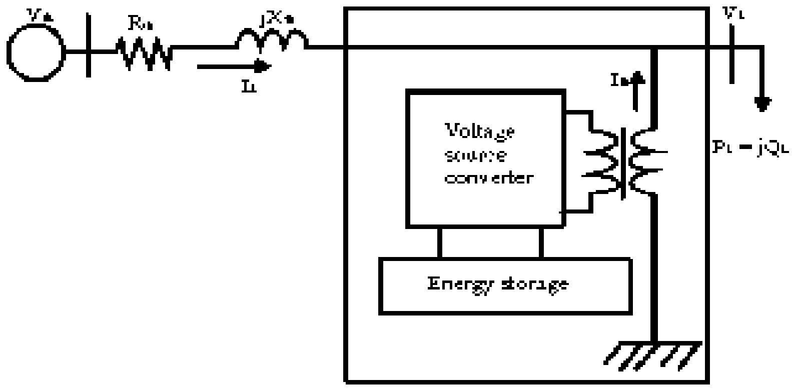

Figure 2: Schematic diagram of D-STATCOM

Fig. 2 shows the schematic representation of the D-STATCOM. The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system [4]. Fig. 2 shows the shunt injected current Ish. Corrects the voltage sag by adjusting the voltage drop across the system impedance Zth .The value of Ish can be controlled by adjusting the output voltage of the converter. The shunt injected current Ish can be written as shown in equation (1).

$$I_{sh} = I_L - I_s = I_L - \frac{V_{Th} - V_L}{Z_{Th}} \quad \text{----(1)}$$

$$I_{sh}\angle\eta = I_L\angle-\theta - \frac{V_{th}}{Z_{th}}\angle(\delta-\beta) + \frac{V_L}{Z_{th}}\angle-\beta \quad \text{.....(2)}$$

The complex power injection of the D-STATCOM can be expressed as,

$$S_{sh} = V_L I_{sh}^{*} \quad \text{.....(3)}$$

It may be mentioned that the effectiveness of the D-STATCOM in correcting voltage sag depends on the value of Z_{th} or fault level of the load bus. When the shunt injected current I_{sh} is kept in quadrature with V_L, the desired voltage correction can be achieved without injecting any active power into the system. On the other hand, when the value of I_{sh} is minimized, the same voltage correction can be achieved with minimum apparent power injection into the system. It is to be noted that voltage regulation at PCC and power factor correction cannot be achieved simultaneously. For a DSTATCOM used for voltage regulation at the PCC, the compensation should be such that the supply currents should lead the supply voltages; whereas, for power factor Correction, the supply current should be in phase with the supply voltages.

D-STATCOM injects a current into the system to correct the voltage sag. For lower voltage sags, the load voltage magnitude can be corrected by injecting only reactive power into the system. However, for higher voltage sags, injection of active power, in addition to reactive power, is essential to correct the voltage magnitude The response time of DSTATCOM is very short and is limited by the power electronics devices. The expected response time is about 25 ms, and which is much less than some of the traditional methods of voltage correction such as tap -changing transformers.

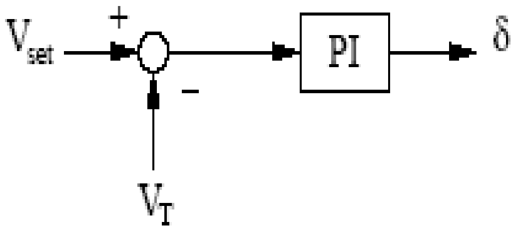

Figure 3: PI Controller

Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response. Because distribution network is a relatively low-power application. The D-STATCOM control system exerts voltage angle control as follows: an error signal is obtained by comparing the reference voltage with the rms voltage measured at the load point [3]. The PI controller as shown in Fig.3 process the error signal and generates the required angle δ to drive the error to zero, i.e., the load rms voltage is brought back to the reference voltage.

A DSTATCOM is capable of compensating either bus voltage or line current. If it operates in a voltage control mode, it can make the voltage of the bus to which it is connected a balanced sinusoid, irrespective of the unbalance and distortion in voltage in the supply side or line current [5]. The use of DSTATCOM as a voltage regulator is to correct the voltage of a specified bus. For the operation of the DSTATCOM as a voltage regulator, we need to specify the following references: terminal voltage, injected current, current through the filter capacitor and load current. Of these, the load current is load dependent and may change at any time. The control is based on sinusoidal PWM and only requires the measurement of the rms voltage at the load point.

The aim of the PWM-based control scheme is to maintain constant voltage magnitude at the point where the load is connected, under system disturbances. The control system only measures the rms voltage at the load point i.e., no reactive power measurements are required. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response.

In this paper, DSTATCOM is used to regulate the voltage against voltage variations by injecting current in shunt with supply voltage. Several strategies have been proposed to control DSTATCOM during voltage variations. Some of these methods try to minimize the energy exchanged by DSTATCOM during compensation or even reduce it to zero. Hence, these methods are called minimum-energy (ME) strategies. Other methods are concerned with reducing the rating and size of DSTATCOM, which occurs when the injected current is 90˚ leading with the source voltage. Therefore, these methods are called minimum rating (MR) control strategies. MR strategies usually require active power for compensation.

III. ID-STATCOM

If the DSTATCOM is to be installed in two or more adjacent feeders, then it will be possible to use a common dc bus for several DSTATCOM. This structure will be called as Interline DSTATCOM or IDSTATCOM as shown in Fig.4, enables active power exchange between two or more DSTATCOMs and therefore extends the compensating range of separate DSTATCOMs. This will be achieved at almost without any additional cost. In an IDSTATCOM structure, the required active power for any DSTATCOM in the faulty feeder(s) will be supplied from other feeder(s) through a common dc link. Thus, it would seem at first glance that the DSTATCOMs in an IDSTATCOM structure will be designed to operate in phase mode, since active power is always available and thus it will be of no concern. But, the amount of power supplied by healthy feeder(s) has certain limitations due to the operational characteristics of these feeder(s).

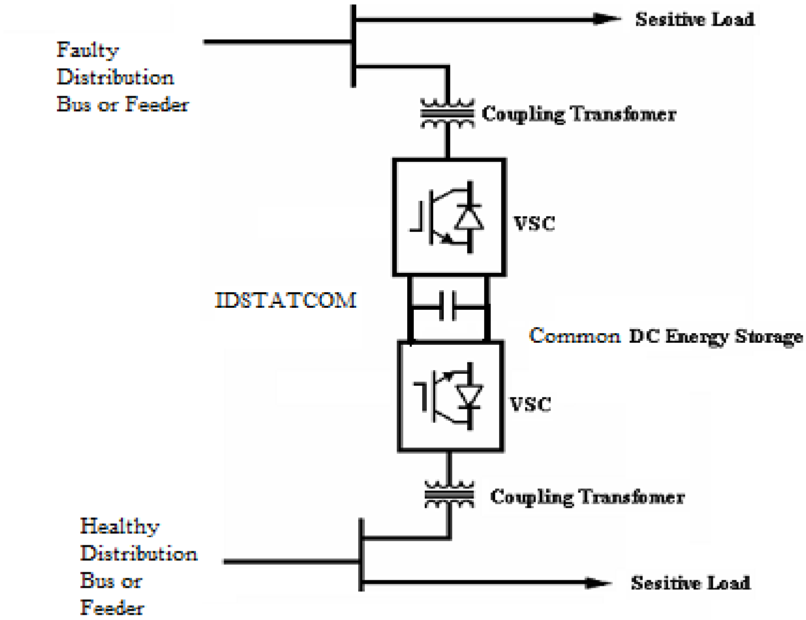

Figure 4: Basic structure of ID-STATCOM

On the other hand, the amount of energy required for compensation in the faulty feeder is not constant and depends on other parameters such as the phase and magnitude of injected current. Therefore in an IDSTATCOM structure will be neither work with minimum energy nor minimum rating strategy. The crucial problem is how to select the size of DSTATCOMs in an IDSTATCOM structure so that all compensating scenarios will be fulfilled while the total rating of the IDSTATCOM will be minimized. This question is directly related to the amount of active power that can be sourced from healthy feeders and that is required for compensation of voltage variation. Since the parameters involved in this problem are highly inter-related, answering the aforementioned question calls for a thorough analysis of an IDSTATCOM structure, this will be the objective of this paper. Specifically, this paper presents a design procedure in which the optimum size of DSTATCOMs in an IDSTATCOM structure will be determined by taking all possible operational scenarios into consideration. The operation of IDSTATCOM will be compared with the case of separate DSTATCOMs to show the improvement in the compensation range of an IDSTATCOM.

IV. SIMULATION RESULTS OF D-STATCOM AND ID-STATCOM

From the simulations results of Fig.5 by using D-STATCOM, the compensation for voltage sag during the period from 3.2 sec to 3.5 sec is performed by VSC with capacitor in D-STATCOM for small voltage sag events and is not satisfactory for deep voltage events. As for deep voltage sag events, the size of capacitor banks in VSC increase with level of voltage events which in turn increases the size and rating of the D-STATCOM which is not a preferable.

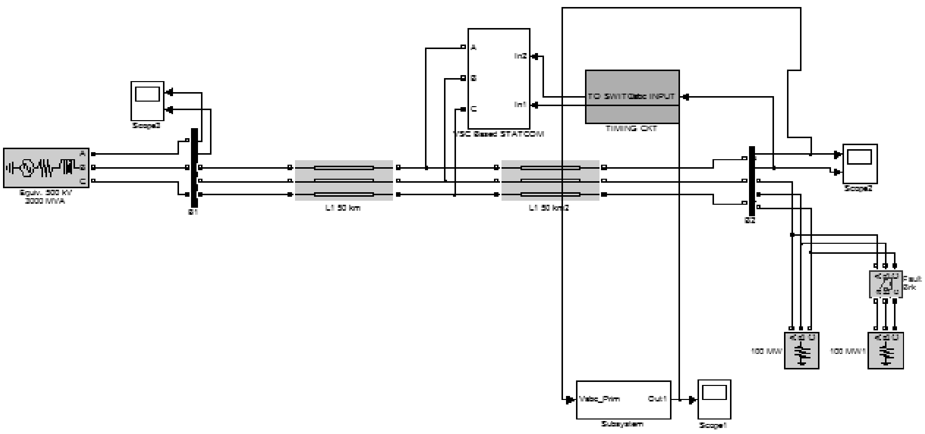

Figure 5: Simulation block of Voltage Sag Distribution line with D-STATCOM

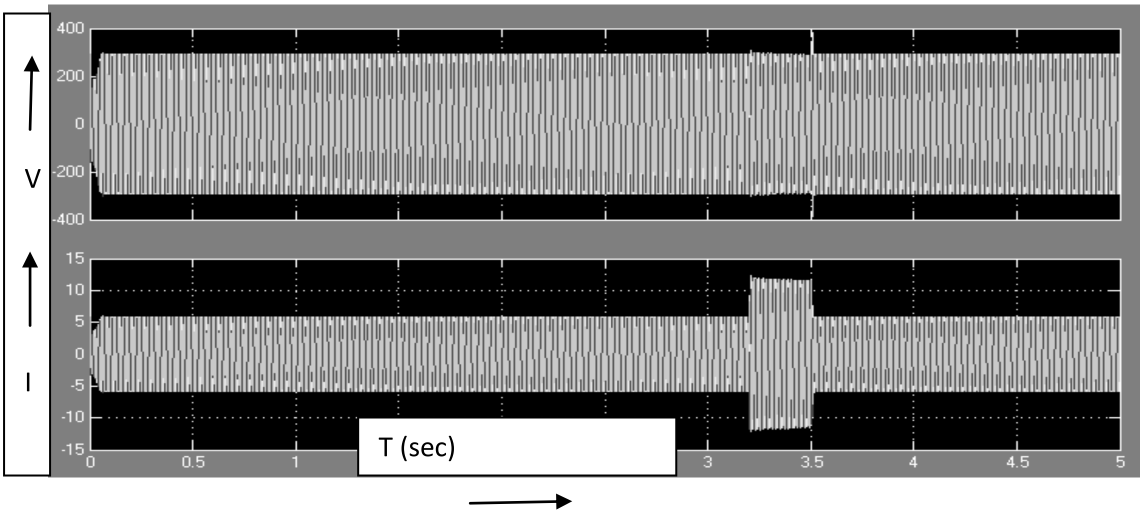

Figure 6: Simulation results of Voltage Sag Distribution line with D-STATCOM

From the simulations results of Fig.7 by using ID-STATCOM, the compensation for voltage sag during the period from 3.2 sec to 3.5 sec is performed by VSC with capacitor in ID-STATCOM for small voltage sag events and as well as for deep voltage events. As for deep voltage sag events, the size of capacitor banks in VSC is small compared with individual D-STATCOM and the size and rating of the ID-STATCOM is small comparing with separate D-STATCOMs. The performance level and response time of ID-STATCOM is also good compared with D-STATCOMs.

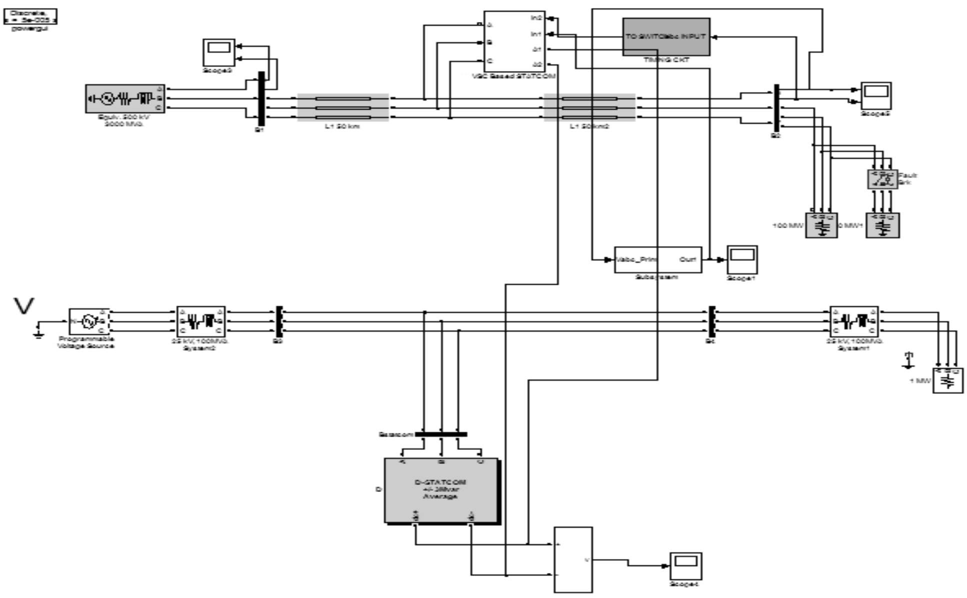

Figure 7: Simulation block of Voltage Sag Distribution line and Healthy Distribution line with ID-STATCOM

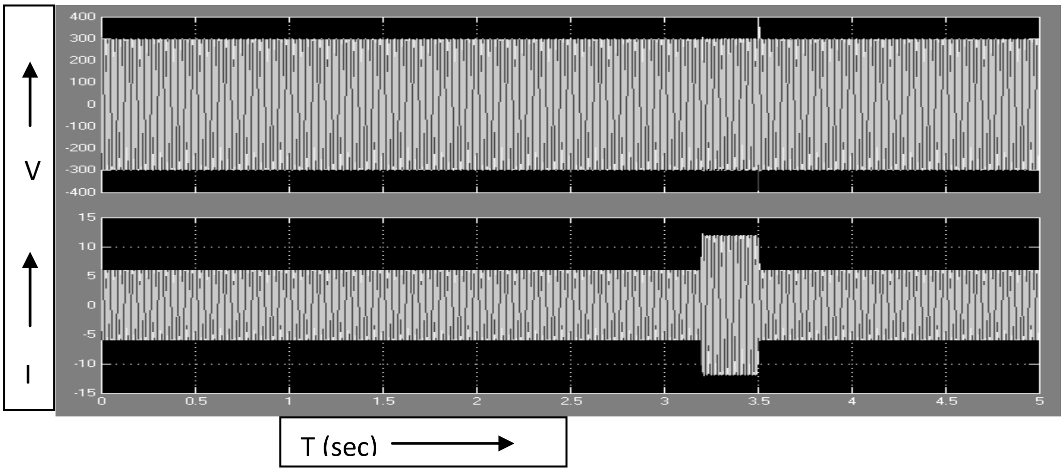

Figure 8: Simulation results of Voltage Sag Distribution line and Healthy Distribution line with ID-STATCOM

V. CONCLUSION

From the simulation results of D-STATCOM and ID-STATCOM, it is clear that compensation for wide range of voltage sag events can be performed effectively by ID-STATCOM than D-STATCOM. The size and rating of ID-STATCOM is small as compared with sum of individual D-STATCOMs. There is no additional cost with ID-STATCOM structure; instead there is reduction in the cost by this compensation technique.

REFERENCES

[1]. John Stones and Alan Collinsion "Introduction to Power Quality, Power Engineering Journal.
[2]. A. Ghosh and G. Ledwich. 2002. Power Quality Enhancement Using Custom Power Devices. Kluwer Academic Publishers.
[3]. R. Mineski, R. Pawelek, I. Wasiak, "Shunt compensation for power quality improvement using a STATCOM controller: modeling and simulation", *IEE Proc.*, Vol. 151, No. 2, March 2004.
[4]. M.H.Haque "Compensation of Distribution System Voltage Sag by DVR and DSTATCOM" *Power Tech Proceedings, 2001 IEEE Porto*, Volume: 1, 10-13 Sept. 2001 Pages:5 pp. vol.1.
[5]. H. Hingorani "Introducing Custom Power" *IEEE Spectrum*, vol.32 no.6 June 1995 p 41-48.