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A Novel Control Method for Mitigation of Voltage Dip in Dual Angle Controlled STATCOM under Fault Conditions.

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ABSTRACT
This paper presents a new control method of reducing the dc link voltage oscillations as well as the voltage dip mitigation. The main improvement is the decrease of negative sequence current, dc voltage oscillation under fault condition and mitigation of voltage dip at the point of common coupling when inductive and capacitive load is connected. The proposed control scheme is for adding appropriate oscillation to the conventional angle controller output. The method improves sensitivity as well as reliable when the STATCOM works under fault conditions and when connected to loads.
Keywords: Dual angle control (DAC), static synchronous compensator (STATCOM).

I. INTRODUCTION

Reactive power compensation is an important issue in the control of electric power systems. Reactive power increases the transmission system losses and reduces the power transmission capability of the transmission lines. Moreover, reactive power flow through the transmission lines can cause large amplitude variations in the receiving-end voltage. Today's power transmission and distribution systems face increasing demands for more power with better quality and higher reliability at lower cost. Developing countries can apply versatile voltage regulation and system stabilization measures in order to effectively utilize the existing transmission networks. The use of power electronics in the form of Static Synchronous Series Compensator (SSSC), Static Synchronous Compensator (STATCOM) and Unified Power Flow Controller (UPFC) is well-established independent of the specific application [1]. A STATCOM is a controlled reactive-power source. It provides the desired reactive-power generation and absorption entirely by means of electronic processing of the voltage and current waveforms in a voltage source converter (VSC). A STATCOM is used for voltage regulation in a power system. Under lightly loaded conditions, the STATCOM is used to minimize or completely diminish the line overvoltage. On the other hand, it can also be used to maintain certain voltage levels under heavy loading conditions [1]. Angle controlled STATCOM are used more than PWM controlled STATCOM because they are providing higher waveform quality with lower losses. the control input to the angle controlled STATCOM is the phase angle difference between VSC and ac bus instantaneous voltage vector (α) [2]. But in the conventional angle controlled STATCOM the dc bus voltage shows oscillations under system fault conditions due to high amount of negative sequence current and the STATCOM unnecessarily trips.

In dual angle control the angle α is splits into two α_{dc} and α_{ac} . The dc part α_{dc} which is the conventional angle-controller output is in charge of controlling the positive sequence VSC output voltage. The oscillating part α_{ac} controls the dc-link voltage oscillations with twice the line frequency to generate required fundamental negative sequence voltages at the VSC output terminals to limit the negative sequence current [3]. But with the dual angle controller when connected to a varying load it shows voltage dip at the point of common coupling. This is a great drawback to the working of dual angle controlled STATCOM. In the proposed control scheme a control method is adopted for maintain the voltage at PCC to constant. And then under varying load condition and different fault condition also the STATCOM can work without tripping.

II. SYSTEM DESCRIPTION

A block diagram representing a grid connected PV system is shown in fig.1.It consists of a STATCOM which is a three phase voltage source converter connected to a capacitor. The dc link voltage is controlled by the dual angle controller. The inverter used here is a 2 level inverter. The three phase VSC performs reactive power controlling, power factor correction, and voltage dip mitigation.

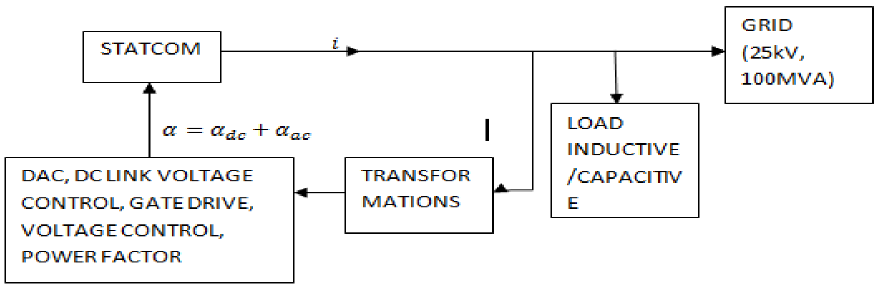

Fig.1 Block diagram representing grid connected STATCOM

The PSCAD model of the grid connected STATCOM with fault applied is shown in fig.2. A breaker is connected at the grid side. The fault applied can be of any type. When the fault strikes the system, the grid protection circuitry detects the fault and opens the breaker. Due to the abnormal condition of the system large negative sequence current flows. The negative sequence current interacts with the inverter switching function to generate second harmonic oscillations in the dc link voltage and current [4]. By the conventional angle controller this dc link voltage oscillations cannot be reduced.

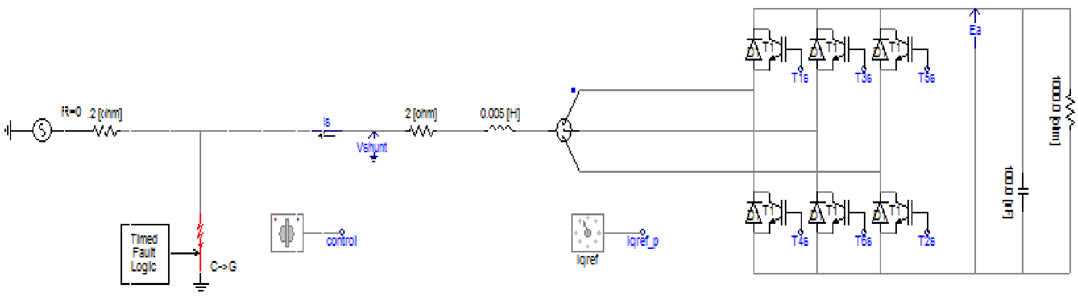

Fig.2 grid connected STATCOM

A strategy is used as shown in fig.3. to reduce the dc link voltage oscillation is dual angle controller. The DAC the phase angle α is splits into two components α_{dc} and α_{ac} . The dc part α_{dc} which is the conventional angle-controller output is in charge of controlling the positive sequence VSC output voltage. The oscillating part α_{ac} controls the dc-link voltage oscillations with twice the line frequency to generate required fundamental negative sequence voltages at the VSC output terminals to limit the negative sequence current. The α_{ac} is obtained by multiplying the amplitude of second harmonic oscillation of q axis component(i_q^+) with the output of negative sequence component. The signal α_{ac} is the required negative sequence voltage to limit the negative sequence current. As the negative sequence current decreases dc link voltage oscillation also reduces.

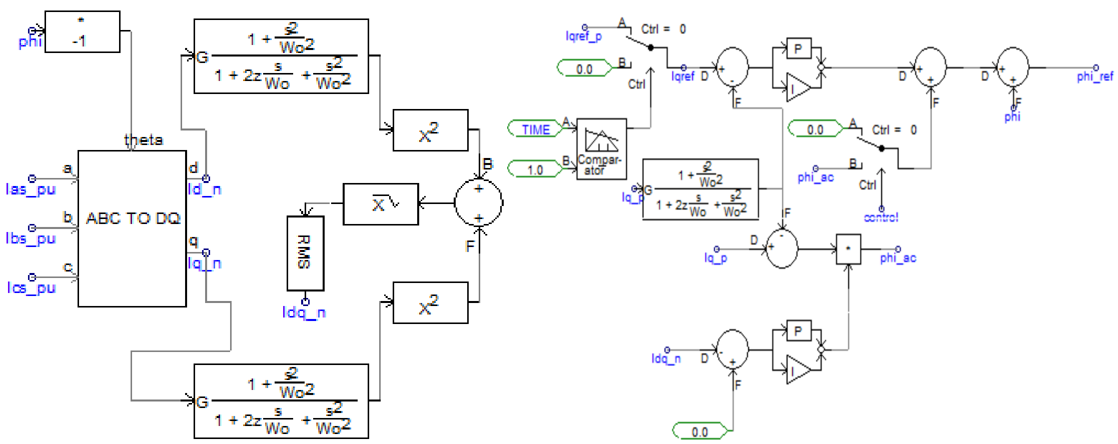

Fig.3 DAC strategy

When the STATCOM is connected to a varying load the STATCOM will suffer voltage unbalance according to the nature of load. The STATCOM can be maintained to a constant voltage to enhance the power flow by voltage controlling at the point of common coupling (PCC).

III. VOLTAGE CONTROLLER FOR MITIGATION OF VOLTAGE DIP

To eliminate the voltage dip, the actual voltage is compared with the voltage at the PCC. If any error is occurred due to the varying load and faults the error signal is given to a PI controller to regulate it. The voltage controller is shown in Fig.4. The voltage controller can be made enable or disable to compare the value of voltage before and after the controlling.

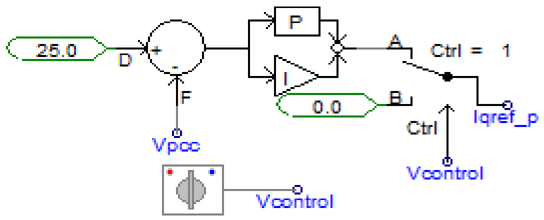

Fig.4 Control given to voltage

The system is connected to a 25kV, 100MVA grid and inductive and capacitive load as shown in Fig.5

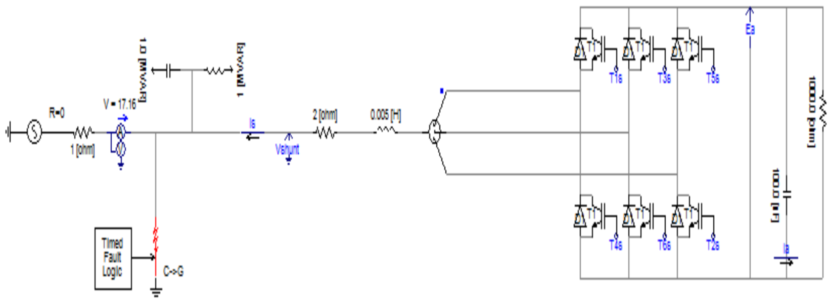

Fig.5 STATCOM connected to load

PWM control is used for switching VSC [5]. The modulating signal produced using voltage control and dc link oscillation mitigation strategy and triangular wave are compared using a comparator as shown in fig.6 and the corresponding signal produced from each comparator will switch the upper IGBTs and the corresponding complementary signals from each comparator will switch the lower IGBTs. Inverter is disconnected from the grid after a particular time by using timed breaker logic in order to prevent the sending of power during fault.

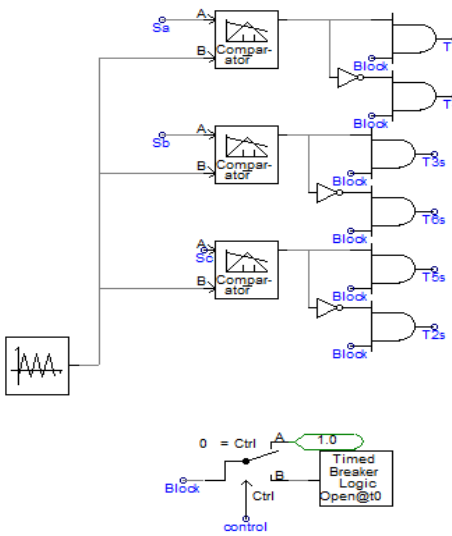

Fig. 6 switching pulses given to VSC

IV. SIMULATION RESULTS

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The whole system is simulated in PSCAD/EMTDC software environment. In the following graphs, it is assumed that an L-L fault strikes the system at *t*=1.0s, then the grid protection circuitry detects the fault and opens the breaker at *t*=1.05s. Table I indicates the parameters used for simulation.

Table I Simulation Parameters

Base MVA	100MVA
Base voltage	25kV
Line inductance (Henry)	0.005H
Line resistance (ohm)	2Ω
Capacitance (Farad)	$100\mu F$
Proportional gain	1
Integral gain	0.1
Resistance	1000Ω

Fig.7 and fig.8 shows dc link voltages with and without using DAC and voltage dip mitigation strategy. Without using the strategy, dc link overvoltage show higher oscillation magnitude. From Fig 8 we can see that the dc link oscillation magnitude drastically decreases.

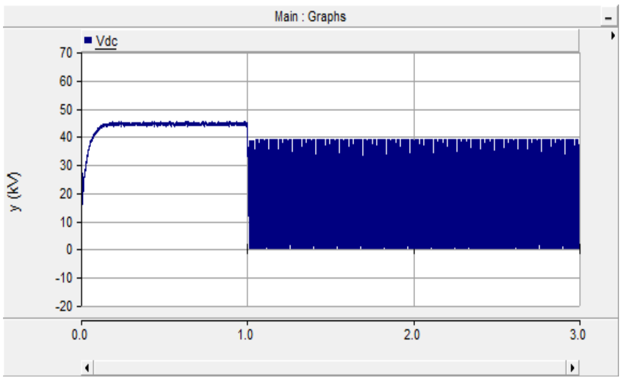

Fig.7 DC link voltage without control

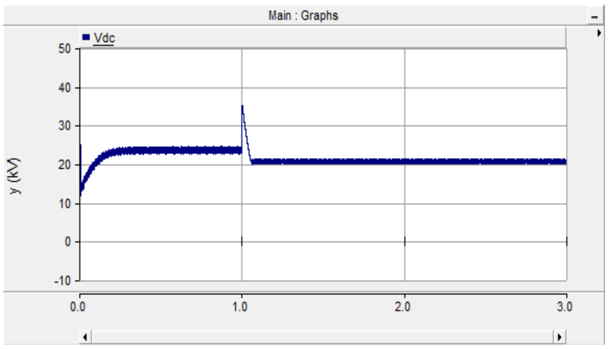

Fig.8 DC link voltage with the control

Fig.9 and Fig.10 shows the variation in negative sequence current with and without the proposed controllers. From Fig.9 we can see that after the fault applied at 1.0s the negative sequence current rms rapidly increases and this leads to dc link oscillation. From Fig.10 it is clear that when the control is enabled the negative sequence current reduces and tends to zero.

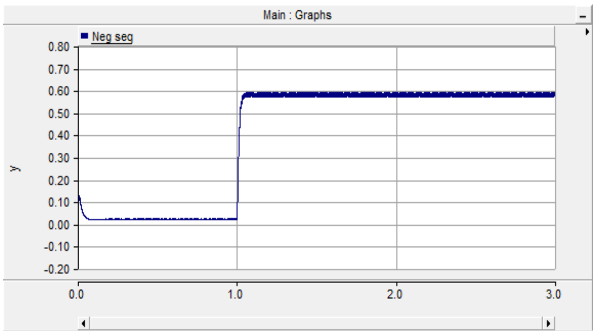

Fig.9. RMS value of negative sequence current without controller

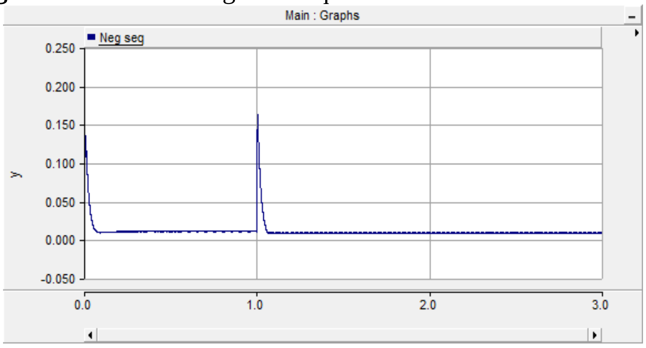

Fig.10. RMS value of negative sequence current with controller.

The voltage at point of common coupling with and without control is shon in Fig.11 and Fig.12 from the Fig. it is clear that without the proposed controller the voltage at PCC is 10.18kV and with the controller it attains a value 17.91kV rms value.

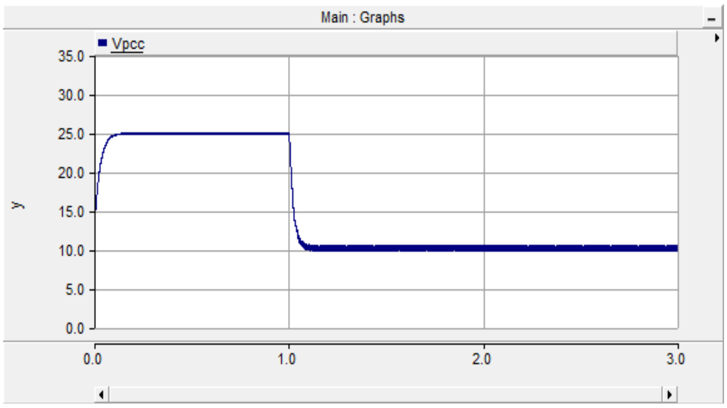

Fig.11. voltage at PCC without control

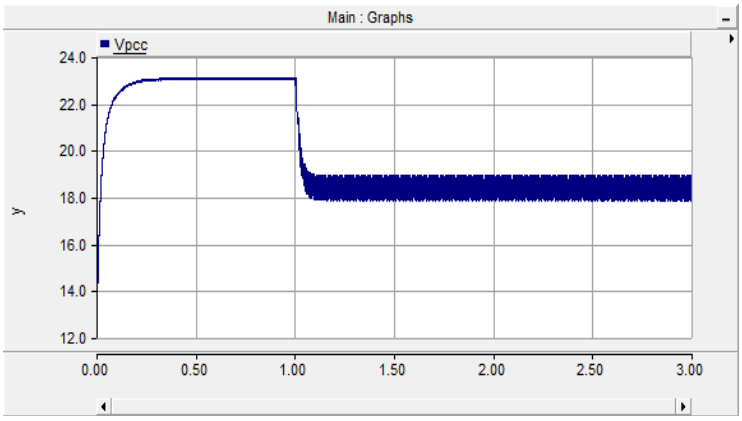

Fig.12. Voltage at PCC with control

V. CONCLUSION

This paper proposes a control structure to eliminate the voltage dip at the point of common coupling when connected to a varying load and SLG fault is applied to phase C. The strategy was developed and demonstrated in PSCAD/EMTDC software. The results shows that by the dual angle controller the dc link voltage oscillations can be reduced. By the proposed voltage control technique the voltage can be eliminated as shown in the graph.

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