A NOVEL ANGLE CONTROL FOR FREQUENCY-LINE SWITCHED STATIC SYNCHRONOUS COMPENSATORS UNDER SYSTEM FAULTS

B.Seshasai[1] , T.Suma[2]
[1]Assistant Professor , [2]M.Tech Student
[1, 2]Dept of EEE, SSCE , Srikakulam

ABSTRACT

The voltage regulation of a power system at utility side i.e., at consumer applications is mainly done by regulating the distribution and transmission systems. The regulation of voltage is done by STATCOM with Voltage Source Converters (VSCs). To attain lower system losses, the Angle-controlled STATCOMs are designed in such a way that they are switched at line frequencies, whereas PWM-controlled STATCOMs are switched at regular frequencies. The imperial Angle-controlled Switched Static Synchronous Compensators (SSSCs) undergo higher currents and cause feasible saturation of transformers that are articulated. This is originated by negative sequence currents and faults at the consumers or utility. This paper recommends an influencing method to enhance the efficiency of angle-controlled STATCOMs under fault conditions and unbalanced conditions. By this propounded technique the oscillation of DC-link voltage and negative component currents will be minimized to the core. The necessity of re-designing of STATCOM is thus minimized. Suitable oscillations are added to the angle-controlled output. So the voltage vector of VSC is now lags or leads the line voltage vector. This is also called Dual Angle control(DAC) since it uses two angles to regulate the VSC. The results are observed in MATLAB.

Keywords: STATCOM, SSSC, Angle-control, DAC, VSC, MATLAB

I INTRODUCTION

The generation or absorption of controlled reactive power has been recognized long back with distinct power electronic switching converters. The power system which is combination of generation, transmission and distributions is controlled by using Voltage Source Converters (VSC) based

STATCOM. The traditional controllers like PWM – controlled STATCOMs are switched at regular frequencies, whereas the Angle-controlled STATCOMs are designed to attain lower system losses and are switched at line frequencies. Recently, Angle-controlled STATCOMs are well in use by utility consumers because of its efficiency, voltage regulation, working and stability improvement. The arrangement of converters in this system might be a combination of some FACTS devices such as Static Synchronous Series Compensator (SSSC), Unified Power Flow Controller (UPFC), Interline Power flow controller (IPFC), Static Synchronous Compensators (STATCOM). Angle controlling is done at Shunt Converter in UPFC and STATCOM.Modern power systems are continuously being expanded and up graded to cater the need of ever growing power demand. This paper explains the problems that are due to poor Power Quality in electrical systems and shows their possible financial consequences and improvement of power quality. Power Quality is characterized by parameters that express harmonic pollution, reactive power and load unbalance It is shown that by using the right technology a variety of Power Quality problems can be solved rendering installations trouble free and more efficient, and can render them compliant with even the strictest requirements.This paper presents a new control structure for high power angle-controlled STATCOMs during normal and fault conditions. The only control input in the angle-controlled STATCOM is phase angle difference between VSC and AC bus instantaneous voltage vector (α). In the proposed controller, α is split into two parts, αdc and αac.The DC part (αdc) which is the conventional angle-controller output is in charge of controlling the positive sequence VSC output voltage. The oscillating part (αac) 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. Since this control scheme uses two angles (α_{dc} and α_{ac}) as control inputs, it is called Dual Angle Control (DAC). The Dual Angle Control stabilizes the STATCOM DC bus during power system faults, and therefore allows the STATCOM to continue operation without tripping. In this paper, we address the issue of limiting the STATCOM negative sequence current, and thus the resulting DC-link voltage oscillations, in high-power angle-controlled STATCOMs, to enable the STATCOM to operate without tripping in the presence of power system faults and AC-system voltage unbalances. This is done by control action, which makes it unnecessary to constrain the design of STATCOM power components to achieve the same task. We give an analysis of STATCOM unbalanced operation, followed by a description of the proposed dual angle control method. The analysis and performance of the STATCOM and the control method is supported by PSCAD/EMTDC simulation, and by experimental results. The experiments were done on a Transient Network Analyser (TNA), which was used to study the STATCOM performance for the NYPA CSC 2×100 MVA installation at the Marcy substation.

II POWER ELECTRONIC DEVICES AND FACTS:

Power Electronics is a field which combines Power (electric power), Electronics and Control systems. Power engineering deals with the static and rotating power equipment for the generation, transmission and distribution of electric power. In electronics, a switch is an electrical component that can break an electrical circuit, interrupting the current or diverting it from one conductor to another.A power electronic switch integrates a combination of power electronic components or power semiconductors and a driver for the actively switchable power semiconductors. The internal functional correlations and interactions of this integrated system determine several types. Diode, Thyristor, IGBT, MOSFET, BJT are popular power electronic devices.The FACTStechnology has a collection of controllers, that can be used individually or co-ordinated with other controls installed in the network, thus permitting to profit better of the network's characteristics of control. The FACTS controllers offer a great opportunity to regulate the transmission of alternating current (AC), increasing or diminishing the power flow in specific lines and responding almost instantaneously to the stability problems. The potential of this technology is based on the possibility of controlling the route of the power flow and the ability of connecting networks that are not adequately interconnected, giving the possibility of trading energy between distant agents. For the FACTS side the taxonomy in terms of 'dynamic' and 'static' needs some explanation. The term 'dynamic' is used to express the fast controllability of FACTS-devices provided by the power electronics. This is one of the main differentiation factors from the conventional devices.

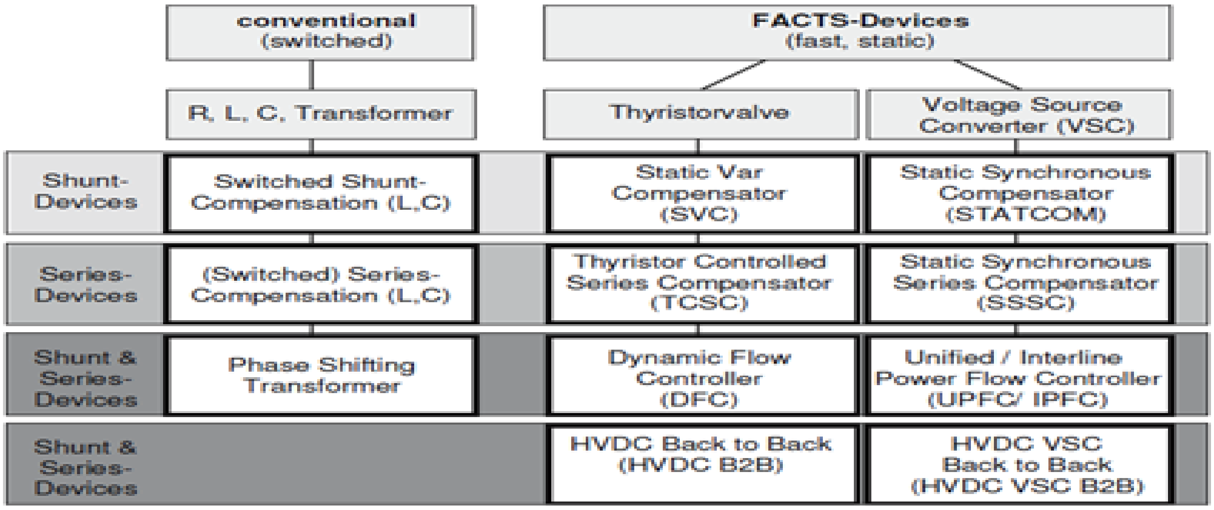

Fig1 Overview of major FACTS-Devices

III STATCOM:

The main function of the STATCOM control is to operate the converter power switches so as to produce a synchronous output voltage waveform that forces the reactive power exchange required for compensation by generating a set of coordinated timing waveforms, which determines the on and off periods of each switch in the converter corresponding to the wanted output voltage. These timing waveforms have a defined phase relationship between them, determined by the converter pulse number, the method used for constructing the output voltage waveform, and the required angular phase relationship between the three outputs. The magnitude and angle of the output voltage determine the reactive current the converter draws from, and thereby the reactive power it exchanges with the AC system. There are two typical STATCOM control schemes: 1) Direct control method is to keep the DC voltage constant and control the reactive output current directly by controlling the converter output voltage through voltage control mechanism; 2) Indirect control method derives the necessary magnitude and angle for the converter output voltage to establish the required DC voltage on the DC capacitor since the magnitude of the AC output voltage is directly proportional to the DC capacitor voltage. Because of this proportionality, the reactive output current can be controlled indirectly via controlling the DC capacitor voltage, which is controlled by the angle of the output voltage.

Static Synchronous Compensators (STATCOMs) are used for voltage regulation in transmission and distribution systems. Unlike PWM-controlled STATCOMs, *Angle-controlled* STATCOMs are switched at line frequency to limit the system losses. In recent years, *angle-controlled* STATCOMs have been deployed by utilities for the purpose of transmission system voltage regulation, voltage stability improvement and increasing operational functionality. Despite the superior feature on voltage waveform quality and efficiency, the practical *angle-controlled* STATCOMs suffer from the over-current (and trips) and possible saturation of the interfacing transformers caused by negative sequence current during unbalanced conditions and faults in the utility. This paper specifically proposes a control structure to improve the *angle-controlled* STATCOMs performance under unbalanced conditions and faults. The main improvement is a substantial decrease in the negative sequence current and DC-link voltage oscillations under power system faults by the proposed control.

This Eliminates the need to redesign the STACOM power components to operate under fault current and DC-link voltage oscillations. The proposed control structure is designed based on adding appropriate oscillations to the conventional *Angle-controller* output that is the control angle by which the VSC voltage vector leads/lags the line voltage vector. Since this control structure uses two angles for controlling the VSC output voltage, it is called *Dual Angle Control (DAC).* In

STATCOM application, the bus voltage is regulated by exchanging reactive power Between STATCOM and power system. In another word, there is no real power exchange during the voltage regulation procedure. As a result, *Id* is equal tozero. In dual angle control method is proposed. Compared with angle control.

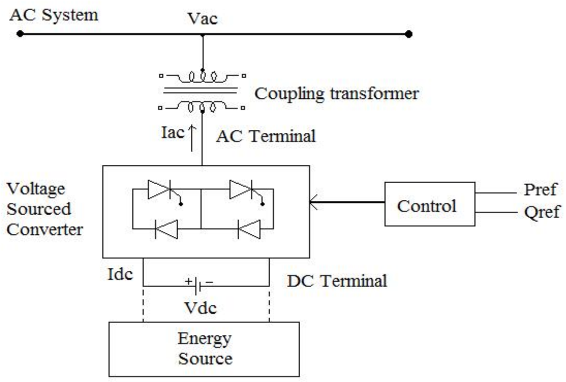

Fig2 Functional block diagram of STATCOM

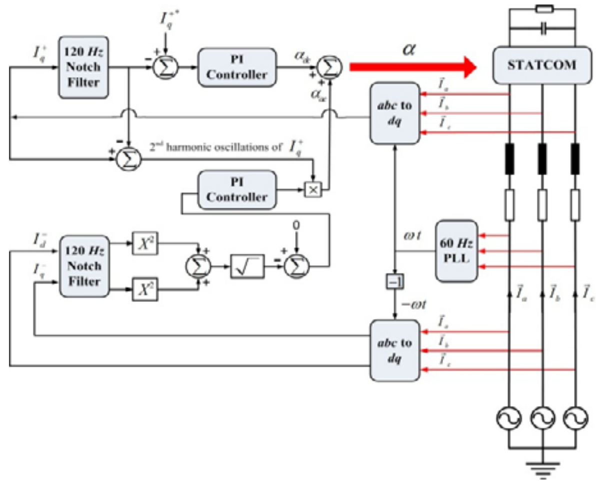

Fig3 Proposed Control structure

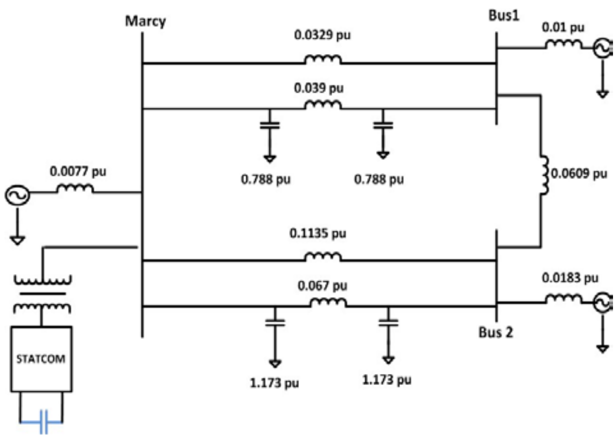

Fig4 Bus AC system model. All the pu values are based on 345 kV and 100 MVA

IV PROPOSED CONTROL

Dual Angle Control strategy is based on generating required fundamental negative sequence voltage vector at the VSC output terminals to attenuate the effect of postulated negative sequence bus voltage under fault conditions and to limit the negative sequence current. The required negative sequence voltage vector is obtained by controlling the 2nd harmonic DC-link voltage oscillations. This part of the paper shows that DC-link voltage 2ndharmonic oscillations are controlled by adding appropriate oscillations to the conventional *angle controller* output .e.iangle α. Itsaw mentioned earlier that α is the ylno control inputfor the *angle controlled* STATCOM. α is a control angle that has a pulse type characteristic nithe normal operation. In daetsy state α Is sevom ti yltneisnarT .orez ot noitcerid evitagen ro evitisop eht drawot dna egatlov knil-CD eht esaercni ro esaerced eht fo snoitairav llamS .orez ot kcab seog neht etats ydaets nesohc a dnuora egatlov knil-CD sessol eht lla nehw tniopare ignored is detaler to angle α perturbation hguorht a driht redro noitcnuf refsnart.

V SIMULATION AND RESULTS

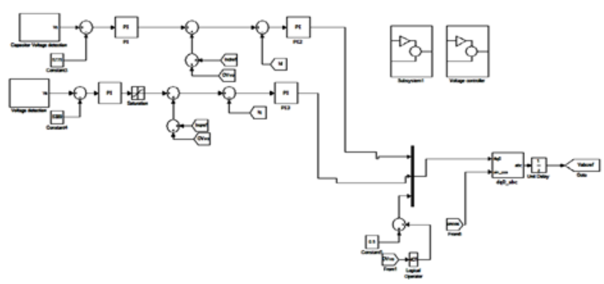

Fig 5 Main Circuit

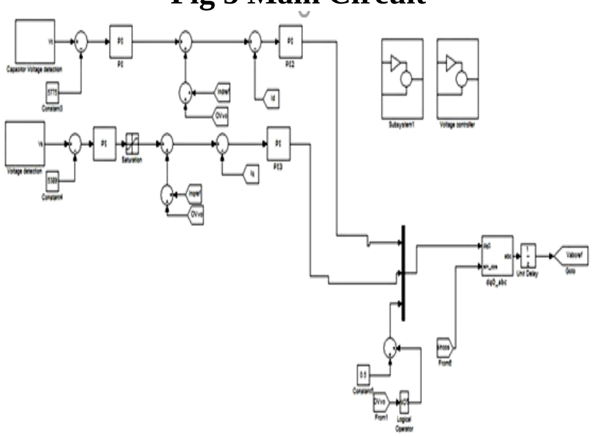

Fig 6 Sub System of Control Block

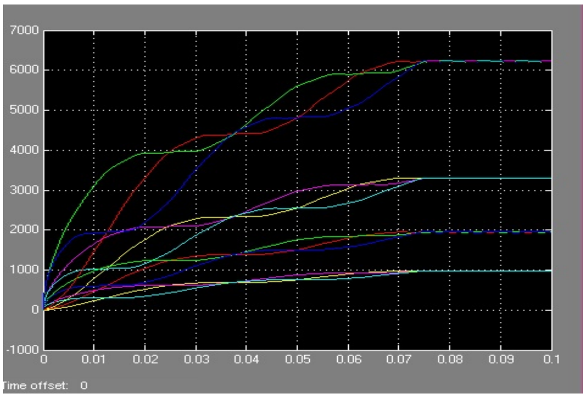

Fig 7 Outputs of Converters

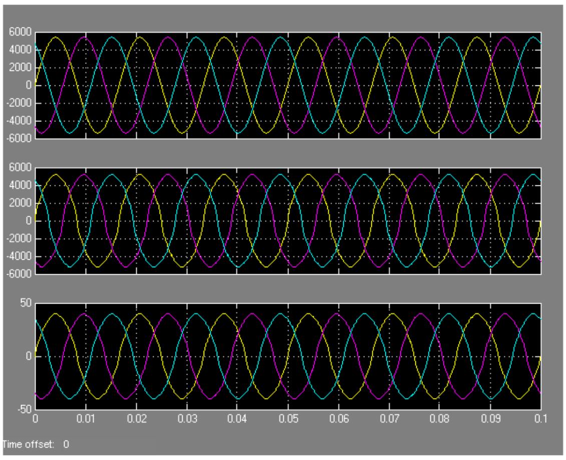

Fig 8 Outputs wave forms of STATCOM and transmission lines

VI CONCLUSION

This paper proposed a control structure to improve the *angle-controlled* STATCOM performance under utility unbalanced conditions and system faults. The main improvement is to significantly decrease the negative sequence current and DC-link voltage oscillations under power system faults through control. This makes it unnecessary to constrain the choice of power component to achieve this desired reduction.

VII ACKNOWLEDGEMENT

The proposed structure is designed based on adding an appropriate oscillation (αac) to the conventional *Angle-controller* output (angle α). The angle α is the angle by which the inverter voltage vector leads/lags the line voltage vector. The angle αac is controlling the DC-link voltage oscillations with twice the line frequency to generate the required negative sequence voltages at VSC output terminals to attenuate the effects of the postulated negative sequence bus voltage. This generated negative sequence voltage results in reduction of the negative sequence current seen by the STATCOM. Since this control structure is using two angles for controlling VSC output voltage, it is called *Dual Angle Control (DAC)* strategy. PSCAD/EMTDC results verified the validity of the proposed control structure. Finally, experimental results form a very unique hardware confirmed the predicted theoretical and simulation results.

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