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Reactive Power and Rotor Angle Control by Using Distributed Static Series Compensator (DSSC) In D- Facts

P. Balaji[1], P. Balaji[2], Anup kumar[3]

[1] P.Balaji, EEE, SAMS College of Engineering, Tamilnadu, India,
[2] P.Balaji, EEE, SAMS College of Engineering Tamilnadu, India,
[3] Auup kumar, EEE, SAMS College of Engineering, Tamilnadu, India

Abstract

Distributed static series compensator is a new device in FACTS family. It is emerged from the SSSC and has relatively low cost and a high reliability. The concept of Distributed Static Series Compensator (DSSC) that uses a low-power single-phase inverter that attaches to the transmission conductor and dynamically controls the impedance of the transmission line, allowing control of active power flow on the line, and also the reliability is further improved due to the redundancy provided by the distributed series converters. Series converter distribution reduces cost because no high-voltage isolation and high power rating components are required. The DSSC concept overcomes some of the most serious limitations of FACTS devices and points the way to a new approach for achieving power flow control. This paper discusses the concept of DSSC & ability of DSSC to increase power flow in a transmission line using PSIM software

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Index Terms: **Single turn transformer, DSSC, Power flow control, IGBT, PLL, LC filter**

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1. INTRODUCTION

IN nowadays power system, there is a great desire for the fast and reliable control of the power flow because of the growing demand of energy, the aging of networks and distributed generation. As the demand for electric power increases it is not possible every time to install new transmission system because of economic consideration & certain restrictions. As a result, power flow control in electric power networks is becoming one of the crucial factors of electric power system development. Only answer to this situation is to make proper utilization of existing transmission system by improving power flow in a line.

The concept of Flexible AC Transmission Systems (FACTS) was proposed to enhance dynamic control in power systems and to improve system utilization. FACTS devices are based on the application of power electronics and high-power high-voltage converters, which can be inserted in series or shunt, or a combination of the two, to achieve many control functions such as voltage regulation, system damping and power flow control. But while FACTS devices have been proven technically and have been available over a decade, market adoption of the technology has been poor. This seems to be largely due to high cost and reliability/availability levels that may not have met utility expectations.

A simple AC power system consists of generators, transmission line & load. A transmission line is represented by series resistance , inductance & capacitance. The power transfer in a transmission line is determined by line impedance & magnitude of phase angle between the end voltages. AC power system performance is improved by control of active power flow. By changing impedance of transmission line or change of angle of voltage applied across the line power flow control is possible. This is ultimately achieved by reactive power compensation.

Flexible AC Transmission system(FACTS) devices provides reactive power compensation, improve voltage profile, reduces voltage dip which improve transmission line performance. FACTS devices though help to make proper utilization of existing power system have its own problems which has limited its use.

A device that is connected in series with the transmission line is referred to as a 'series device'. Series devices influence the impedance of transmission lines. The principle is to change (reduce or increase) the line impedance by inserting a reactor or capacitor. To compensate for the inductive voltage drop, a capacitor can be inserted in the line to reduce the line impedance. By increasing the inductive impedance of the line, series devices are also used to limit the current flowing through certain lines to prevent overheating.

Distributed Static Series Compensator (DSSC) is one of the DFACTS devices. DSSC is acting as variable impedance which when connected to transmission line alters impedance of transmission line which then governs the power flow. This paper presents DSSC model & experimental result of 138 Kv line using PSIM software. Also it is explained here how DSSC helps to increase power transfer capability of line.

2. CONCEPT OF DSSC

The concept of DSSC was introduced to illustrate the feasibility of a distributed FACTS or D-FACTS approach which is a similar approach to the implementation of high power FACTS devices, but can provide higher performance and lower cost method in order to enhance system reliability and controllability. DSSC uses multiple low-power single-phase inverters that attaches to the transmission conductor &dynamically control the impedance of transmission line allowing control of active power flow on the line. With this feature line impedance can be increased or decreased or may remain unchanged depending upon the control signal received.

A DSSC module as shown in Fig. 1, consists of a small rated (~10 kVA) single phase inverter and a Single Turn Transformer (STT), along with associated controls, power supply circuits and built-in communications capability. The STT is a key component of the DSSC. It uses the transmission conductor as a secondary winding and is designed with a high turns ratio which reduces the current handled by the inverter and allows the use of commercial IGBTs to realize low cost. The transformer core consists of two parts that can be physically clamped around a transmission line, forming a complete magnetic circuit only after the module is clamped around the conductor. Also, each module has a control circuit together with a communication system in order to have a coordinated operation when operated as a group.

The weight and size of each DSSC module is low enough to allow the unit to be suspended mechanically from the power line and since it does not require supporting phase-ground insulation, the module can be applied at any line voltage ranging from 13-500 kV. The first component, which is in quadrature with line current results in reactive power generation or consumption & consequently decreases or increases the effective line reactance The second component is in phase with the line current & provides compensation of power losses in the inverter & regulation of the dc bus of the inverter.

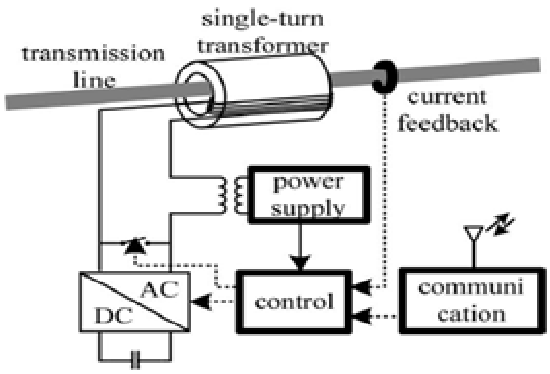


Fig. 1: Circuit schematic of a DSSC module

The concept of DSSC is originated from SSSC which is a FACTS device. More safety & improved controllability of power system is provided by distributed nature of DSSC. The another benefit of DSSC is while connecting DSSC in a line there is no need to break the line is can be easily suspended from the conductor or configured as a replacement.

DSSC unit consists of multiple low rated, single phase VSC that are attached to the transmission line by single turn transformer fig (2) DSSC units is remotely controlled via wireless communication. It is floating on the line .Units are clamped on transmission lines, requiring no additional land there by eliminating the footprint.

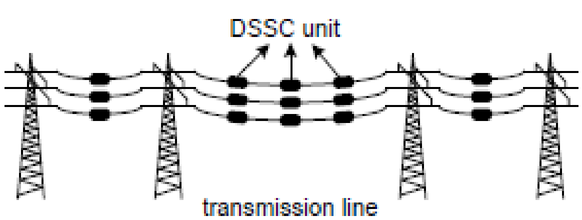


Fig. 2: DSSC connected in transmission line

The operation of the DSSC can be summarized as follows: As the module starts up, the inverter voltage is in phase with the line current and real power is extracted from the line to charge the DC bus capacitor. After charging the capacitor to a predetermined voltage, the unit is controlled so that it injects a quadrature voltage or reactive impedance in series with the line, resulting in an increase or decrease of transmitted power along the transmission line. When there is no longer a need for compensation, the unit is bypassed and turned off, meaning that the DSSC must have the ability to be turned on and off as many times as needed during operation. Therefore by deploying a large number of DSSC modules on a transmission line – in order to gain an adequate reactive impedance injection - the overall system benefit can only be achieved by coordinated control. This coordination can be done using an isolated communication link such as a radio receiver incorporated in each module or through the use of other commercially available communication systems such as power line communication.

Fig. 2 shows a conceptual schematic of D-FACTS devices deployed on a power line so as to alter the power flow by changing the line impedance. Each module is rated .at about 10 kVA and is clamped on the line, floating electrically and mechanically on the line. Each module can be controlled so as to increase or decrease the impedance of the line, or to leave it unaltered. With a large number of modules operating together, it is possible to have a significant impact on the overall power flow in the line. The low VA ratings of the modules are in line with mass manufactured power electronics systems in the industrial drives and UPS markets, and suggests that it would be possible to realize extremely low cost. Finally, the use of a large number of modules results in high system reliability, as system operation is not compromised by the failure of a small number of modules.

Equation (1) shows how power flow varies with the line reactance. Control of real power flow on the line thus requires that the angle or the line impedance XL be changed. A phase shifting transformer can be used to control the angle. This is an expensive non-scalable solution and provides limited dynamic control capability. Alternatively, a single series compensator can be used to increase or decrease the effective reactive impedance *L X* of the line, thus allowing control of real power flow between the two buses. The impedance change can be effected by series injection of a passive capacitive or inductive element in the line. Alternatively, a static inverter can be used to realize a controllable active lossless element such as a negative or positive inductor or a synchronous fundamental voltage that is orthogonal to the line current.

$$P12 = \frac{V1V2}{X_L} \sin\delta \qquad (1)$$

where *V1* and *V2* are the bus voltage magnitudes δ is the voltage phase difference and *XL* is the line impedance.

3. PSIM SIMULATION

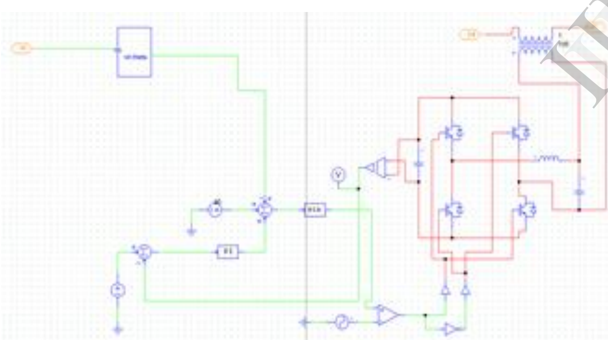


Fig 3. PSIM Module of DSSC

A DSSC module is designed using PSIM software. A single phase IGBT inverter is connected with LC filter connected through the single turn transformer .A dc capacitor is also connected at other end of the inverter. For controlling inverter output pulse width modulation is used. A simple control circuit has been designed to govern output of the inverter.

3.1 CONTROL SYSTEM OF DSSC

The designed control circuit requires output of PLL (Phase Locked Loop) i.e theta , output of PI controller which is obtained by comparing reference Vdc & actual Vdc that is measured across DC capacitor & a phase shift of -90o . The above three signals are input to 3 point summer & the resultant output signal is given to sine function block which will generate sinusoidal output signal of input. This generated sinusoidal signal is given to the comparator & second signal to the comparator is triangular wave voltage signal. These two signals are being processed in a comparator using PWM technique & the output of comparator acts as gate signal for IGBT & thus inverter output is controlled. Fig 3 represents control circuit for DSSC.

Inverter output is connected to STT through LC filter. The STT has the ratio 105:1 number of winding towards inverter side is 105. The complete DSSC module is connected to line using STT. The line current is received by PLL which will generate theta & after completion of mechanism suitable voltage is induced in the line.

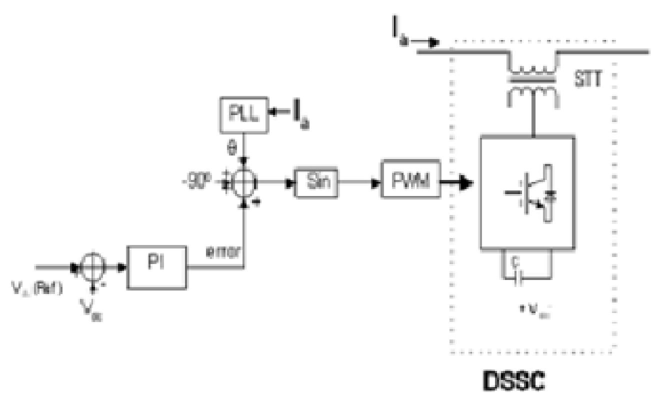


Fig. 4 Control circuit of DSSC

3.2. PHASE LOCKED LOOP

A digital PLL with " phase shifter "method is used in control circuit of DSSC fig 5 shows PSIM model of real time digital PLL This PLL provides fast dynamic response. PLL is used to generate respective angle theta & the input to PLL is line current which is given by current sensor. Fig 5shows output of PLL i.e theta

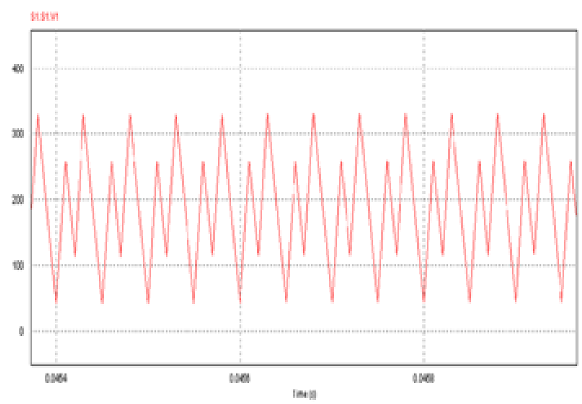


Fig .5. Theta (output) of PLL

3.3 SYSTEM UNDER CONSIDERATION

A 138 Kv line is considered for simulation . The line has an impedance of 0.17+j0.8 per mile [1]. The power transmitted in line

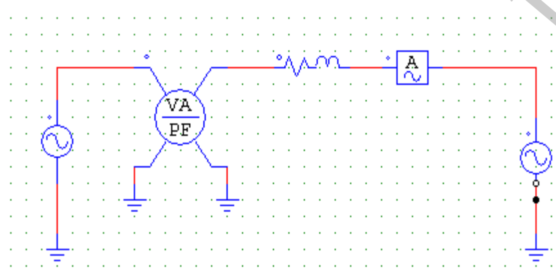


Fig. 6 . System Simulation Model

The system in Fig 6 is a simple transmission line with some amount of power flow. Now in the same system the amount of power flow can be increased by connecting a DSSC module in the transmission line.

When one DSSC module is connected in the line the amount of power flow in a line increases by some KW . As the number of DSSC module increases in a transmission line at each step the there is increment in power flow in a line.

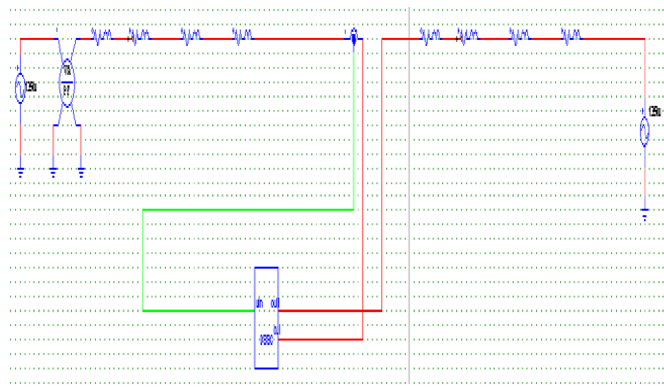


Fig- 7 System Simulation model with one DSSC

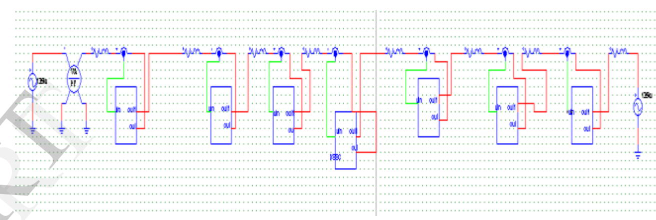
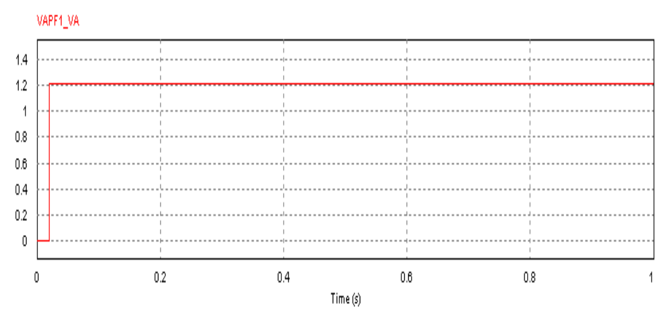
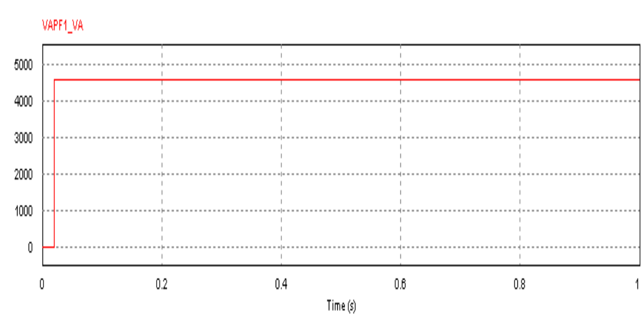


Fig .8. System Simulation model with seven



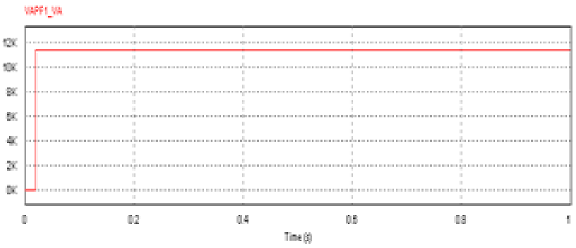
DSSC



Without DSSC

Fig 9. Without DSSC

Fig.10 -One DSSC



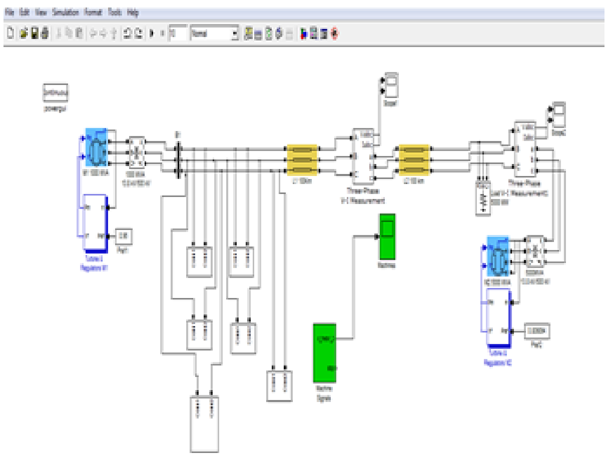


Fig 11. Six DSSC in three bus system using MATLAB

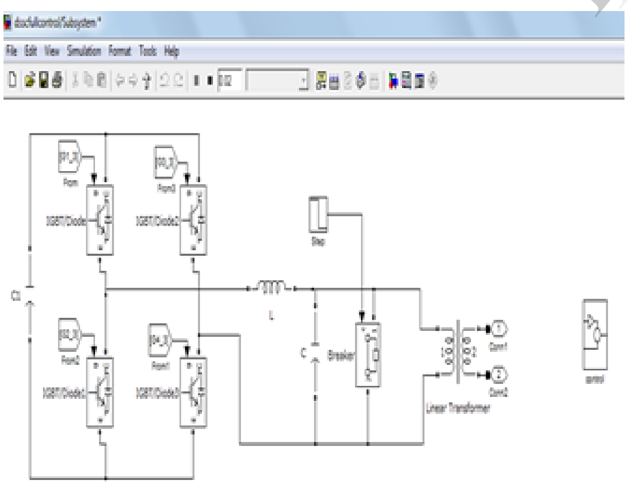


Fig 12. SUB -BLOCK OF DSSC

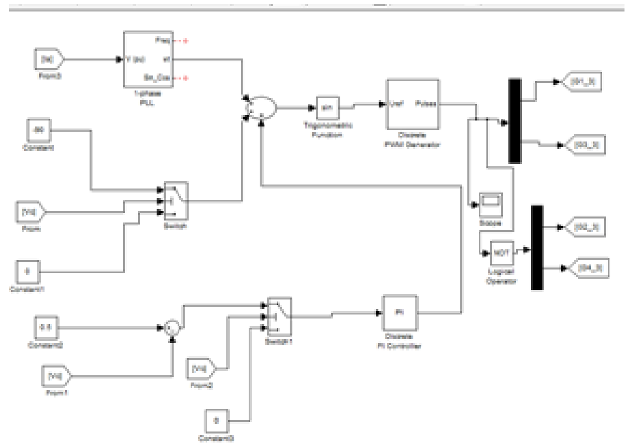


Fig 13. SUB BLOCK OF DSSC

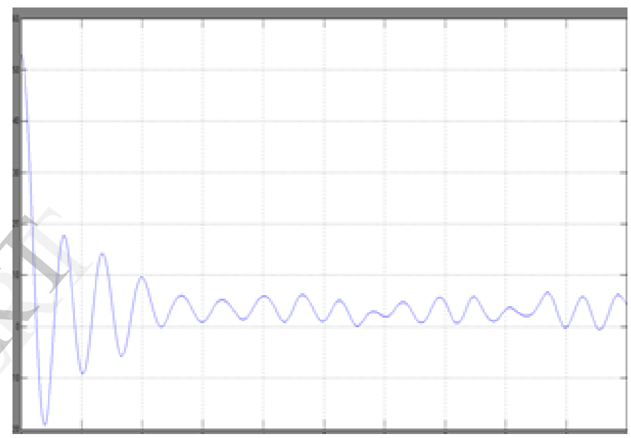


Fig. 14 ROTOR ANGLE

FUTURE WORK

DSSC is connected in DPFC for series converter, DPFC is advanced from UPFC.DPFC is derived from UPFC, higher reliability and low cost. DPFC is a combination of shunt and series converter. In series number of DSSC converter is connected in the transmission line. If any one of the series converter is failed the converter is bye-passed by using crow Bar diode. Without any interruption the other converter will take place the system to improve the DPFC performance.

CONCLUSION

This paper presents a new approach to controlling power flows on the transmission and distribution grid. Distributed FACTS or D-FACTS devices using commercially available low power devices, offer the potential to dramatically reduce the cost of power flow control. The power flow in a line can be increased by adjusting the impedance or reactance of line. One of the method of increasing power flow in a transmission line is connecting DSSC in a line which acts as an active voltage source . The simulation results with & without DSSC have been discussed earlier which indicates that by connecting number of DSSC in a distributed fashion along the transmission line the desired increase in power flow is possible. The number DSSC converter is also connected in transmission line to improve the power flow in transmission and distribution grid.

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BIOGRAPHIES

BALAJI PERUMAL received his Diploma in Electrical And Electronics from I.R.T Polytechnic College, Chennai in 2007.He received the Bachelors degree from Srinivasa Institute of Engineering College in 2010. He is Received his Masters in Power System Engineering from B.S. Abdur Rahman University in 2013 Chennai. He is Currently Working in SAMS College of Engineering as a Assistant Professor. His Field of interest include DPFC(Distributed power Flow Controller), Power System Protection and FACTS Device.