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Power Flow Improvement Using Distributed Static Series Compensator

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***Abstract*—Present scenario of electrical power system need to increase power transfer capability of existing transmission line. In order to achieve this various FACTS(Flexible AC Transmission System) & DFACTS (Distributed FACTS) devices have been connected to existing transmission line which helps to improve the performance of transmission line. Distributed Static Series Compensator (DSSC) is one of the DFACTS device. This paper discusses the concept of DSSC & ability of DSSC to increase power flow in a transmission line using PSIM software.**

***Index Terms*—DFACTS, DSSC, Power flow control, PSIM, IGBT, PLL**

I. INTRODUCTION

THE demand for electricity is tremendously increasing day by day which causes existing transmission line to increase power transfer capability. As the demand for electric power increases it is not possible every time to install new transmission system because of economic consideration & certain restrictions. Only answer to this situation is to make proper utilization of existing transmission system by improving power flow in a line.

A simple AC power system consist of generators, transmission line & load. A transmission line is represented by series resistance , inductance & capacitance.[12] The power transfer in a transmission line is determined by line impedance & magnitude of phase angle between the end voltages.[12] 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.

DFACTS devices are advanced form of FACTS devices . FACTS devices are called lumped devices as they have to get connected at single point in a transmission line whereas

DFACTS devices have an advantage of getting distributed along the line. Distributed Static Series Compensator(DSSC) is one of the DFACTS device. DSSC is acting as a 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

II. CONCEPT OF DSSC

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.[1]With this feature line impedance can be increased or decreased or may remain unchanged depending upon the control signal received. Single turn transformer (STT) is most important component of DSSC. It has high turns ratio example 105:1. The transmission line conductor acts as secondary winding for DSSC. With the help of STT voltage is injected in a line. The power supply provides the required power for DSSC components. The single phase inverter , dc capacitor, & the LC filter work together , to generate desired voltage to inject it into the transmission line. The voltage output of the single phase inverter is controlled by pulse-width modulation (PWM) techniques & has two components. [2]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[2]. 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.[2]

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[14]. 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 or the conductor support clamp on an insulator. [1] Fig 1. Shows internal structure of DSSC .

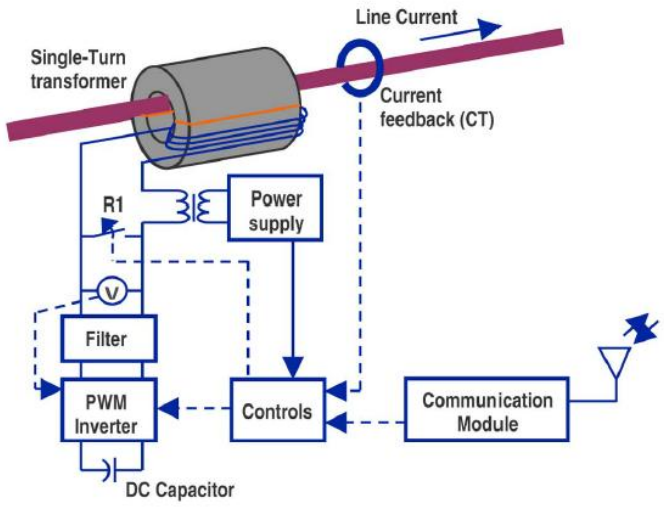

Fig 1. Structure of DSSC [1]

III. DESCRIPTION OF DSSC MODEL IN PSIM

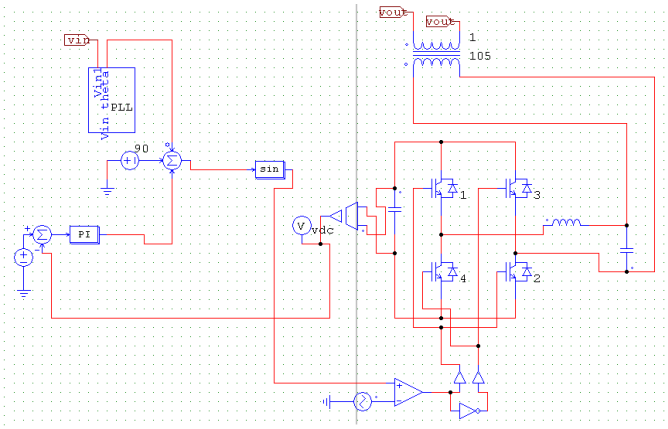

Fig 2. PSIM Module of DSSC

A small DSSC module is designed using PSIM software. A single phase IGBT inverter is designed with LC filter at its output to reduce generated output & 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 .

A. *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 -90^o . 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.

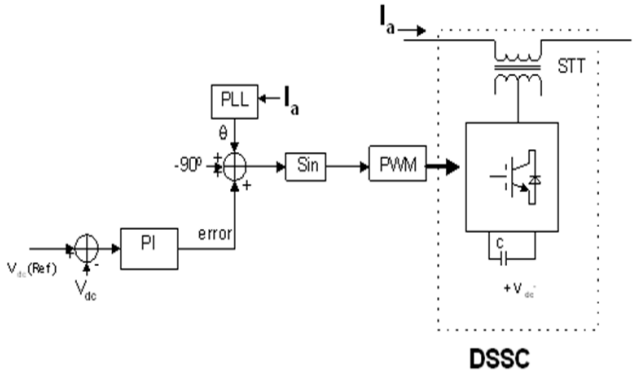

Fig 3. Control circuit of DSSC [14]

Inverter output is connected to STT through LC filter . This STT has the ratio of 105:1 i.e number of windings 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.

B. *Phase Locked loop*

A digital PLL with " phase shifter "method is used in control circuit of DSSC.[13] fig 4 shows PSIM model of real time digital PLL .[13] This PLL provides fast dynamic response[13] . PLL is used to generate respective angle theta & the input to PLL is line current which is given by current sensor. Fig 5 shows output of PLL i.e theta

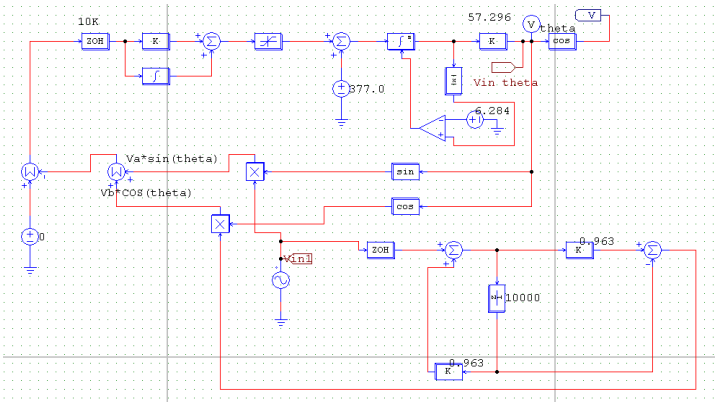

Fig 4. PSIM model of PLL[13]

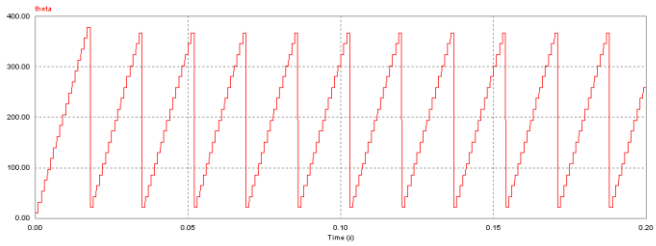

Fig 5 Theta (output) of PLL

IV. 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 517.32576 MW.

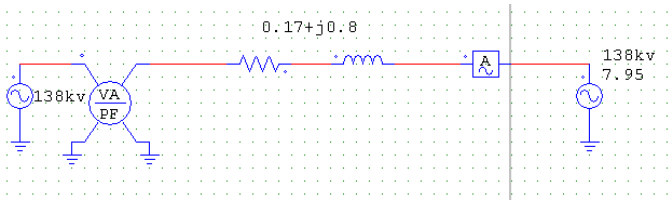

Fig 6 System simulation model

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.

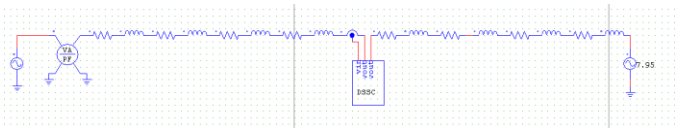

Fig 7 System simulation model with one DSSC

The amount of power in a transmission line after DSSC getting connected to the line becomes 517.67616 MW i.e power in a line increases by350 KW

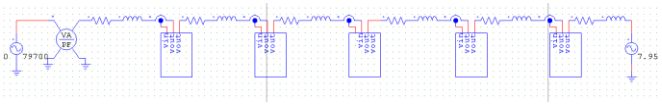

Fig 8. DSSC connected to line in a distributed manner

TABLE I
INCREASE IN POWER FLOW AFTER CONNECTING DSSC TO THE LINE

No of DSSC	Amount of power In a line (MW)	Amount of power increase
0	517.32576	
1	517.67616	350 KW
2	517.77216	96 KW
3	517.86816	96 KW
4	517.9632	95 KW
5	518.0592	96 KW
6	518.1552	96 KW
7	518.25024	95 KW

From table 1 it is clear that with increase in DSSC module corresponding power flow increases in line this implement that the reactance of line has been reduced or some amount of voltage is being injected in a line. Fig 9 shows DC link Capacitor voltage waveform. The capacitor charges up to 900 V .. The reference Vdc is set as 900V.

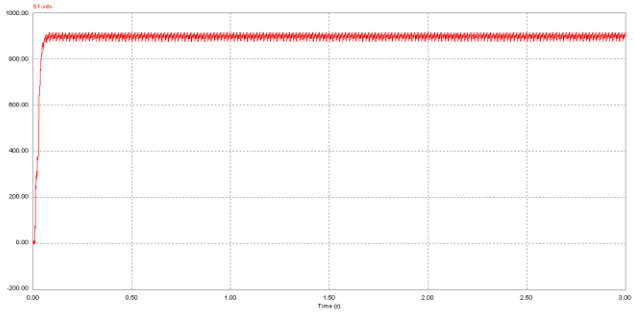

Fig 9. DC capacitor voltage waveform

V. CONCLUSION

A simple power system has been studied to find out solution for ever increasing demand of electricity from existing transmission system. 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. This would also be a more effective method from the economic & environmental point of view. There is a situation to implement this methodology in practical as early as possible.

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