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CONCEPT OF DISTRIBUTED FACTS POWER FLOW CONTROL

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ABSTRACT:

In transmission grid, for voltage and power flow control 'FACTS' devices are used. But high cost and reliability concerns have limited the wide spread deployment of FACTS solutions. Implemented version of FACTS device, D-FACTS is introduced as a way to remove these barriers. D-FACTS device, name is distributed static series compensator DSSC, connects directly to power line. By changing line reactance of transmission line D-FACTS devices are distributed in such way that desired power flow control can be achieved effectively. Details of implementation and system impact are presented in the paper along with case study of DSSC device.

I. INTRODUCTION:

The modern industrial infrastructure demands increasing amounts of electricity. Yet in a semi-regulated utility environment and in the face of increasing public sentiment against locating power lines in their communities, and using of existing asset base more effectively create a big issue. The utilities have done a good job in ensuring availability of reliable cost effective electricity and saving of power [5]. Day by day for fulfilling the power demands, the saving of power becomes more important than the generation of power. These conditions create a compelling need for controlling of power flow by changing the reactance of line. For power flow on the grid, FACTS devices [2]. such as a STATCOM, SSSC connected in series or shunt, to obtain desired functions including voltage regulation, system damping and power flow control. Typical FACTS devices can operate at up to 345KV and can be rated as high as 200MVA.But FACTS system is not have the commercial acceptance due to number of reasons: i) Shunt connected devices that operate in parallel with grid and are not very effective for achieving power flow controlling. In some instances, series capacitors are used to increase the capacity of long lines.ii) High fault current (60,000Amps) and basic insulation requirements (1000 KV) stress the power electronics system, especially for series systems that are required for power flow control [1]. iii) Complete system lead to shutdown when fault is developed. iv) Lumped nature of system and initial over rating of devices to accommodate future growth provides poor return on investment (ROI). v) High cost resulting from device complexity and component requirement e.g. the mercury convertible static compensator (CSC) cost $ 54 million [4]. So there is a general consensus that the future power grid will need to be smart and aware, fault tolerant and self-healing, dynamically and statically controllable, and asset and energy efficient, such implemented and advance form of FACTS device is called as a D-FACTS device. Example of series type of D-FACTS devices such as distributed series impedance (DSI)), distributed series reactor (DSR) can, dynamically and statically change the impedance of line to control power flow. Instead of connecting one single unit. To a system, distributing light weight, self excited modules which are float on the power line with small rated low cost power devices acting on a per phase of the transmission line to obtain the power flow control. This can be achieved by injecting a voltage or impedance in the line. It operates with or without communications [1]. D-FACTS device has certain advantages to providing a higher performance and lower cost method for enhancing T & D system reliability and controllability. It operate in a high electric and magnetic field environment to operate in a hostile environment including wide temperature range; ability to operate without pooling and having low cost (less than $100 /KVA) [1]. it doesn't require line voltage and high insulation level for installation purpose with small rating of device (~ 10 KVA).

II. DSSC:

DSSC device have a small rating (~ 10KVA) and consists of single-phase inverter, single turn transformer (STT), along with associated controls, power supply circuits and built-in communications capability. DSSC module has the low weight and unit to be suspended mechanically from the power line [1]. It does not require supporting phase ground insulation; the module can easily be applied at any transmission voltage level. Figure 1 shows for a DSSC device, and figure 2 shows the circuit diagram of DSSC device.

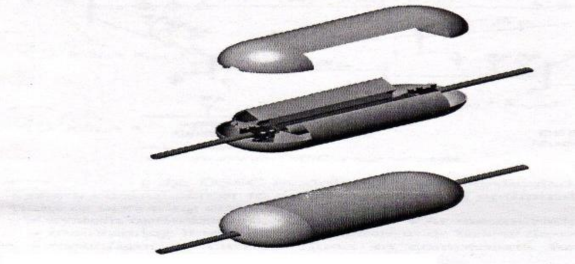


Fig. 1. DSSC concept showing clamp - on capability

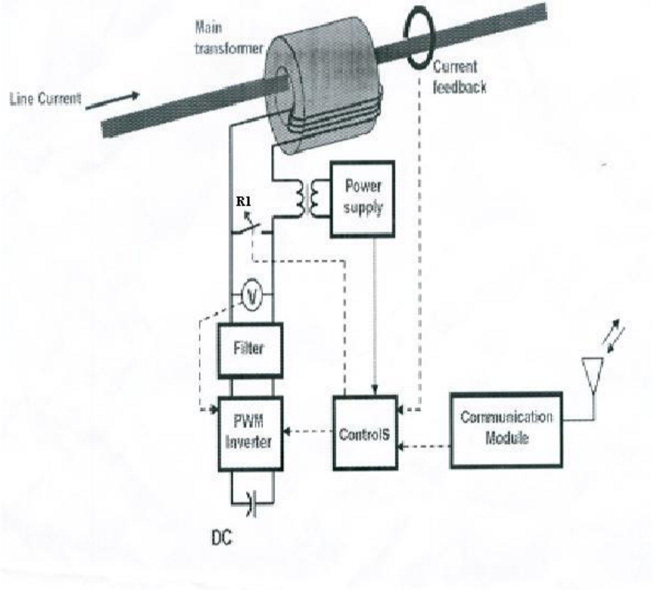


Fig. 2. DSSC circuit schematic.

A current transformer is used to generate control power, allowing the DSSC module to operate as long as the line current is greater than a minimum level, say 150 Amp. The single-phase inverter uses four IGBT devices The inverter output voltage is controlled and has two components. The first represents the desired impedance to be injected, second is in phase and allows compensation of power losses. All the commands for changes are received from a central control center using a wireless or power line communication (PLC) technique [3]-[6].

STT is a main component of the DSSC module is designed with high turns ratio say 75:1. Designing the inverter for 500V RMS output would then allow the DSSC module to inject 7V RMS value leading or lagging, corresponding to ± 10KVA in the line. So such module can be designed to weight less than 45Kg (100 1b) making direct clamp on mounting on the transmission conductor. The STT also allows the inverter to the operated under fault conditions. For instance at a fault current of 50,000 Amp, the inverter current is still only 667Amp.

III. OPERATION OF DSSC MODULE:

A controlled transmission line implemented with multiple DSSC modules realize significant benefits at highest level, for power control are –

- Reduce system congestion of power line.
- Enhance asset utilization of the system.
- Enhance system reliability and capacity of transmission line under contingencies.
- Enhance system stability [3]-[4].

Figure 3 shows DSSC modules, deployed on select lines, or on all lines. The over all operation of the system is controlled by PLC in case of system faults or communication link failure. A system level command could be for the DSSC modules to injected are desired impedance or voltage as a function of line current. For instance the line impedance could automatically increase above a current set point, causing current to be steered to other lines that are lightly loaded. The implementation form of the DSSC modules gives the optimization function or operating conditions including following specified data

- Maintaining lines out of congestion or below thermal limit of current.
- Reconfiguring current flows to compensate for tripped lines.
- Forcing power to flow along contract paths of the line.
- Controlling power flow through flow-gates [4].

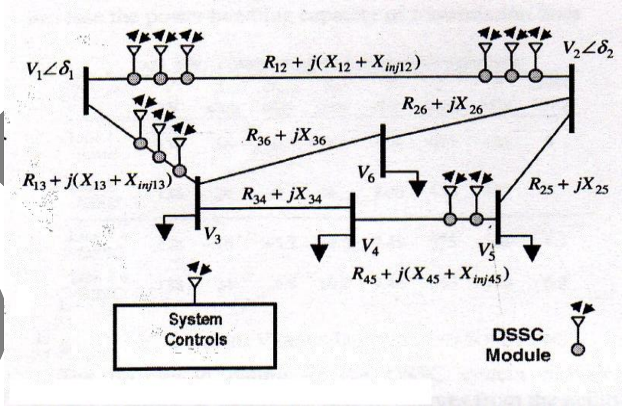
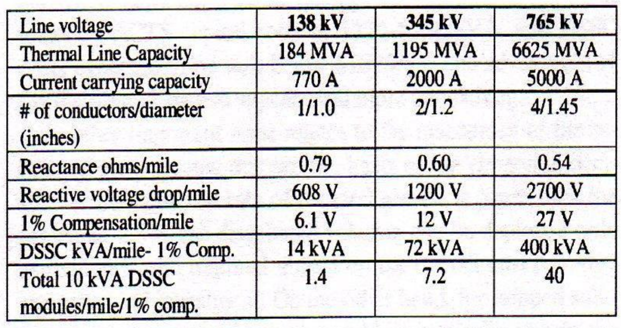


Fig. 3. Meshed network system DSSC implementation

The DSSC modules with specified ratings (Earlier mentioned) targeted for 138KV to 500KV system with the maximum value of impedance control and projected at up to ± 10-20% of actual line impedance. Under rated current condition provides the fine power flow control under increasing the system demand. Table I shows the realistic applications of DSSC module at 138 to 765KV lines.

Table I. Calculation of number of DSSC modules to change line impedance by 1%



Line voltage	138 kV	345 kV	765 kV
Thermal Line Capacity	184 MVA	1195 MVA	6625 MVA
Current carrying capacity	770 A	2000 A	5000 A
# of conductors/diameter (inches)	1/1.0	2/1.2	4/1.45
Reactance ohms/mile	0.79	0.60	0.54
Reactive voltage drop/mile	608 V	1200 V	2700 V
1% Compensation/mile	6.1 V	12 V	27 V
DSSC kVA/mile- 1% Comp.	14 kVA	72 kVA	400 kVA
Total 10 kVA DSSC modules/mile/1% comp.	1.4	7.2	40

Taking a 138KV line as an example, it is seen that the reactive voltage drop is 608V / mile at rated current (Corresponding to 0.79 Ohms / mile) a 1% change in the impedance thus requires an injection of

6.08V / mile corresponding to a combined DSSC rating of 14KVA per mile based on the 3 phase injection. A variation of ± 20% of line impedance would thus need 280KVA or 28 of the 10 KVA DSSC modules/mile

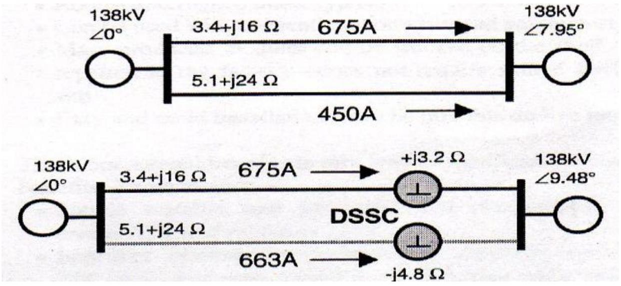


Fig. 4. DSSC uncompensated (Top) and with DSSC compensation (Bottom).

Table II. Line parameters for example of figure 4

V1 = V2 = V	79.7 kV (138 kV L-L)
Line 1 impedance Z1=R1+jX1	20 miles x (0.17+j 0.8) ohms/mile
Line 2 impedance Z2=R2+jX2	30 miles x (0.17 + j0.8) ohms/mile
Line 1 thermal rating, I1 max	750 A
Line 2 thermal rating, I2 max	750 A
Line 1 current I1	2 V sin(δ/2)/Z1
Line 2 current I2	2 V sin(δ/2)/Z2

Figure 4 shows a simple example of how the DSSC can be controlled. Two lines of unequal length are used to transfer power from bus 1 to bus 2. The assumed line parameters are listed in table II. Settings of parameter angle δ= 7.95° yield line currents of I1 = 675A and I2 = 450A, and power transferred along the lines is P1 = 161MW and P2 = 107MW for a total power transfer of 268MW between the buses. Assuming a DSSC in each line, increasing X1 by 20% and decreasing X2 by 20% allows use of larger phase angle δ= 9.48°, which results in I1 = 675A giving P1 = 161MW, and I2 = 663A and P2 = 158MW, for a total power transfer of 319MW between the buses. The power transferred through line 2 has increased by almost 50%, while line 1 has been controlled to well with in it's a thermal limit. Approximately 10.9MVA of control action, achieved with 1092DSSC modules spread over 50 miles of transmission lines – 7.3 modules per mile per conductor, resulted in 51MW of additional power flow between buses. This number would be even more advantages at higher system voltages [4].

Table III. Power transfer between two buses

	V kV	X_L ohm	X_{inj} ohm	X_{eff} ohm	δ deg	I_L Arms	P MW	DSSC MVA
Line 1 initial	138	16	0	16	7.95	675	161	0
Line 2 initial	138	24	0	24	7.95	450	107	0
Line 1 + DSSC	138	16	+3.2	19.2	9.48	675	161	4.4
Line 2 + DSSC	138	24	-4.8	19.2	9.48	663	158	6.5

IV. RESULT:

The transmission line implemented with the multiple DSSC modules gives the optimization function of line. Example conforms that, the ability of the DSSC to control loop flows, to manage congestion, and to increase the power handling capacity of the transmission line.

V. CONCLUSION:

Line allowing power flow control. Implementation of system level control, uses This paper has presented, the DSSC (Low cost, small size device) uses multiple low power single phase inverter that clip on to the transmission conductor to dynamically control the impedance of the transmission of DSSC modules can be used either increasing or decreasing the line impedance, allowing current to be "Pushed", away from or "Pulled" into a transmission line in a whole networked system. Hence DSSC concepts overcome the FACTS devices.

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