Power Flow Analysis using Bundle-Controlled Line Impedance Modulator and Performance Comparison with Thyristor- Controlled Series Compensator Technology

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Abstract— This paper presents a comparison of DFACTS device under development for the management of power flow under steady-state and dynamic conditions, the bundle-controlled line-impedance modulator (LIM) and its performance with TCSC In its simplest form, an LIM is made of switching modules connected in series with transmission-line segments whose bundles have subconductors insulated from each other. A module contains one switch in series with each subconductor of a bundle and the modules are anchored to dead-end towers in place of yoke plates. Finally, the LIM performance is analysed.

Key words: Bundle Conductors, Compensation, Flexible AC Transmission Systems (FACTS), Line-Impedance Modulator (LIM), Load-Flow Control, Power System Simulation, Power System Stability, Power Transmission Lines

I. INTRODUCTION

In recent years, the challenges of power-flow management in electrical transmission grids have increased significantly due to the integration of power systems across ever-expanding regions. To improve power-flow management, devices known as flexible ac transmission systems (FACTS) have been proposed [1]. Some of these devices can be installed at transmission-line stations to adjust power flow in each transmission line so that the power flow will be safe, stable, and balanced. FACTS devices for high-voltage and high-power applications are large pieces of equipment physically erected on the ground. Due to their relatively high cost, these devices are not widely implemented in power transmission networks at the present time.

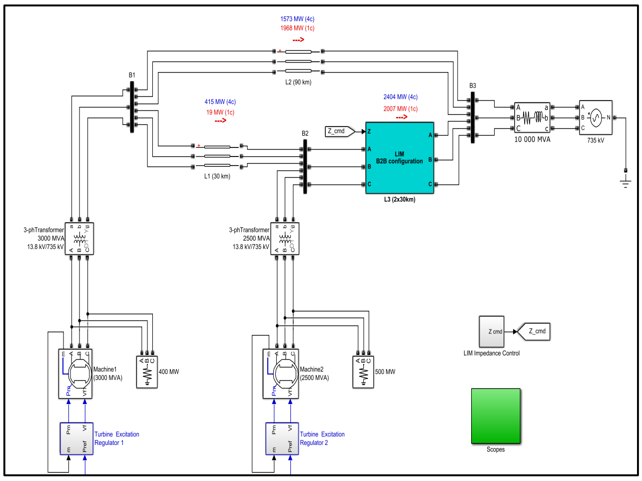
More recently, distributed flexible AC transmission system (D-FACTS) devices [3],[4] such as the Distributed Static Series Compensator (DSSC) have been designed to address power control types of problems. D-FACTS devices attach directly to transmission lines and can be used to dynamically control effective line impedance. Also, D-FACTS devices are smaller and less expensive than traditional FACTS devices which may make them better candidates for wide scale deployment.

Adhesion of ice to surfaces causes problems for many industries, including aviation, telecommunication, navigation, power network equipment, and transportation. In the case of overhead electrical lines, the combination of wind and ice could cause damages, sometimes leading to power outages and dire socio-economic consequences. The January 1998 ice storm in North of America is a good example of such consequences [4]. Subsequently, the need for new solutions led to the development of several de-icing and anti-icing methods destined to overhead power lines, which were the subject of several technical reports and publications [4-6], resulting in an exhaustive and detailed review of the different de-icing and anti-icing techniques, already available and in development.

This paper is about a specific application of a new concept of FACTS device, the bundle-controlled line-impedance modulator (LIM), introduced in [2], which is not erected directly on the ground but anchored to a limited number of existing dead-end towers in place of yoke plates. This new technology involves a method for managing the power flow in an electric power network by modulating the series impedance of an HV power line with bundled conductors. More specifically, it is based on the implementation of switching modules (SMs) in segments of a transmission-line phase conductor made of bundled subconductors. A number of these switching devices must be distributed throughout the power grid and controlled in a coordinated way to manage the power flow. The system and method can, in principle, be used for modifying the power flow through an electric grid in static or dynamic mode. As will be explained, the approach to power-flow control with this new FACTS device is to minimize the equipment cost by exploiting the inherent properties of transmission lines and eliminating the foot print by anchoring small SMs to a limited number of transmission towers.

II. MODELLING IN MATLAB/SIMULINK

This MODEL shows two generators and a 10,000 MVA equivalent power system interconnected by three 735-kV transmission lines.



As a rule, on a high-voltage transmission line, several conductors are usually provided for each line phase to reduce corona losses and the impedance. Within a bundle, yoke plates and spacers hold individual sub conductors separate from and parallel to each other. Normally, sub conductors are short circuited at yoke plates. The line-impedance modulator can operate with any number of sub conductors per bundle but, for the purposes of this thesis, we will restrict our discussion to a 735-kV power transmission line with two sub conductors per bundle.

As shown in Fig.7.1, the line impedance can be modulated by installing switching modules (SMs) at a number of locations and in all three phases of the line allowing either one, two, or three conductors to be disconnected. One subconductor in each bundle is left unswitched at all times.

III. RESULTS

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So in our model this is connected on L3 line.
When we run this model and observe the following values

1) When all Switch are On

'V_b: L3 (2x30km)/Sw1_1 ' = 4.73 Vrms -154.34°
'V_b: L3 (2x30km)/Sw1_2 ' = 4.61 Vrms -155.51°
'V_b: L3 (2x30km)/Sw1_3 ' = 4.62 Vrms -155.49°
'V_b: L3 (2x30km)/Sw1_4 ' = 4.74 Vrms -154.31°
'I_b: L3 (2x30km)/Sw1_1 ' = 473.22 Arms -154.34°
'I_b: L3 (2x30km)/Sw1_2 ' = 461.31 Arms -155.51°
'I_b: L3 (2x30km)/Sw1_3 ' = 461.60 Arms -155.49°
'I_b: L3 (2x30km)/Sw1_4 ' = 473.53 Arms -154.31°

2) When One Switch is Open

'V_b: L3 (2x30km)/Sw1_1 ' = 6.45 Vrms -153.94°
'V_b: L3 (2x30km)/Sw1_2 ' = 5.71 Vrms -156.02°
V_b: L3 (2x30km)/Sw1_3 ' = 6.33 Vrms -154.77°
'V_b: L3 (2x30km)/Sw1_4 ' = 5098.57 Vrms -74.48°
'I_b: L3 (2x30km)/Sw1_1 ' = 645.16 Arms -153.94°
'I_b: L3 (2x30km)/Sw1_2 ' = 571.10 Arms -156.02°
'I_b: L3 (2x30km)/Sw1_3 ' = 633.48 Arms -154.77°
'I_b: L3 (2x30km)/Sw1_4 ' = 0.00 Arms 0.00°

3) When Only One Switch Is Closed

'V_b: L3 (2x30km)/Sw1_1 ' = 17.03 Vrms -154.60°
'V_b: L3 (2x30km)/Sw1_2 ' = 13482.21 Vrms -75.28°
'V_b: L3 (2x30km)/Sw1_3 ' = 14797.45 Vrms -74.33°
'V_b: L3 (2x30km)/Sw1_4 ' = 13574.74 Vrms -74.96°
'I_b: L3 (2x30km)/Sw1_1 ' = 1702.74 Arms -154.60°
'I_b: L3 (2x30km)/Sw1_2 ' = 0.00 Arms 0.00°
'I_b: L3 (2x30km)/Sw1_3 ' = 0.00 Arms 0.00°
'I_b: L3 (2x30km)/Sw1_4 ' = 0.00 Arms 0.00°

At t=0 s, all the LIM's switches are closed. Power flows in each line are annotated in blue in the example next to each transmission lines.

At t=0.5 s, the impedance signal Zcmd ramps from 1 to 1.642 pu as shown by the yellow trace. For each values of Zcmd, the look-up table provides the corresponding switch combinations. The switch combinations transmitted to the switching modules are sampled here every 0.1 s. This gives the discretized impedance signal Zdisc (magenta).

A. Power Flow Control

To control power flow, it is desirable to be able to maintain or change quantities such as line impedances, bus voltage magnitudes, and phase angle differences. There are many power controller devices which affect some or all of these parameters. The well-studied FACTS devices are included in this power controller category.

B. Line Deicing

- Graph 3 also shows the switch currents of the phase A switching module located on the bus B2 side.
- With all switches closed, switch currents are initially 465 A rms.
- With all but one switch opened at t=3.9 s, it can be seen that the switch current of subconductor 2 reaches 1533 A rms.
- Hence, although the power flow in line L3 has been reduced by 17%, the subconductor current has increased by a 3.3 factor.
- Such a current is large enough for simultaneously deicing by the Joule effect three subconductors (one per phase) in both 30-km BCL segments.

IV. CONCLUSION

The significance of intensive use of FACTS devices in the emerging electricity market environment demands more robust FACTS control methodologies. To control power flow, it is desirable to be able to maintain or change quantities such as line impedances, bus voltage magnitudes, and phase angle differences. There are many power controller devices which affect some or all of these parameters.
We have concluded following disadvantages of TCSC:

1) A limited amount of power can be sent over a transmission line.
2) Conductors and equipment may be damaged by overheating if too much current is drawn.
3) Non-linear in nature and produce harmonics in the output signal

Also we have important advantge of using BCL i.e deicing:

1) Atmospheric icing may be problematic for many industries, including electric utilities. The combination of wind and ice could cause damages, sometimes leading to power outages. So by increasing the voltage and current with the help of switch will increase the temp and hence ice will melt.

So to improve power flow control and remove ice from transmission line a bundled control line impedance modulator is implemented here. It include the concept of switching module and the result obtain shows that the current increases to very high amount which in turn will melt the ice.

The qualitative results presented in this study show that an LIM with snubbers presents better performance.

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