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Original Article

Power Flow Enhancement by TCSC using Two Different Types of Pulse Generators

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Abstract *- The availability of power to every sector of the country is essential for the growth and economic development of the country. But there is a huge gap between power demand and power generation. Due to a mismatch in the development of generation and transmission systems and an increase in load demand, the existing systems are overloaded. The performance of the power system deteriorates due to an increase in power demand, size and complexity of the networks. Due to interconnections, stability problems arise in the systems. In this scenario, FACTS devices are used to improve the overall performance, transmission capacity and stability of the system with minimum investment. TCSC is used to enhance the power flow in the system by adjusting the impedance parameter of the line. In the proposed work, the power flow is enhanced in the system using TCSC fired by two different types of pulse generators. They are the Time-based Pulse Generator block of MATLAB and a novel Power Pulse Generator where the gate pulses are obtained from a pulse generator synchronized on the current. Both the single-phase and three-phase representation of the Kanpur Ballabhgarh transmission line with TCSC is used in the present work. The THD analysis is also done in this work which showed that the power quality of the system is improved using TCSC. The load flow analysis is performed in a three-phase representation of the system, which showed that the total generation is increased after using TCSC based on both types of pulse generators.*

Keywords *- Compensation, Oscillations, Pulse generator, Power system, Performance, TCSC.*

1. Introduction

The use of the FACTS device TCSC, a series controller, brings a lot of benefits to the system, like an increase in power transfer capacity, reduced losses, improved stability, and reduced oscillations. By controlling the firing angle of the thyristor, the TCSC provides variable compensation in place of fixed compensation by series capacitors.

The system has a reactive power contribution from the TCSC as it has a capacitive element that is added in series with the line. It improves the reactive power balance of the system and improves the voltage stability and power quality of the system. [1,2,3] These actions of TCSC are instantaneous and are of a self-regulatory nature.

The ATC (Available transfer capacity) of the system is improved using TCSC, which indicates the amount of additional power that can be transmitted from one place to another [3]. The device has been installed for Tamil Nadu 400 kV transmission network to improve the system's performance [4]. Modelling of TCSC for 9 bus test systems has been done for reduction of transmission loss. TCSC was connected between different buses, and results were analyzed. There was an improvement in voltage profile and total active power loss.[5]

2. Different Types of Pulse Generators

The different types of pulse generators used in the proposed work are:

2.1. Type 1 Pulse Generator: Time-Based Pulse Generator block of MATLAB

The type 1 Pulse Generator used in the system is the block of Pulse Generator from MATLAB Simulink library. The various parameters of the block, like amplitude, time delay, pulse width, and period are set according to the firing angle required for TCSC in inductive and capacitive modes. The time-based pulse type is used for both the single and three-phase representation of the system.

2.2. Type 2 A Novel Power_Pulse Generator

This is a new pulse generator used in the present work to generate the firing angles to the TCSC. The gate pulses are obtained from a pulse generator synchronized with the source current. The firing angle is varied using current synchronization and is given to the TCSC. A sawtooth and a staircase generator are used internally. The internal details of the two Pulse generators used are shown in Fig. 1and Fig. 2 [9,10,11,12]

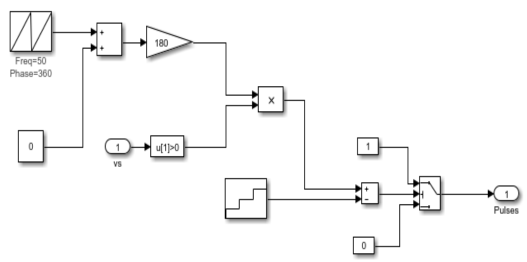

Fig. 1 Novel Power_Pulse Generator 1

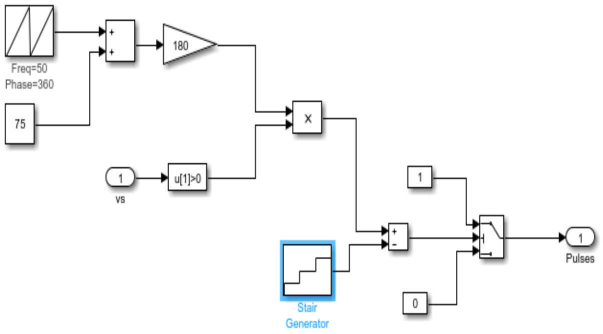

Fig. 2 Novel Power_Pulse Generator 2

3. Performance Analysis

The technical data of the Kanpur Ballabhgarh 400 KV transmission line, whose length is 400 Km, is as under:

Resistance of the line =1.28 ohms Inductance of the line=-0.4178 Henry
The inductance of TCSC= 0.07829 Henry. Capacitance of TCSC= 32.3503e-06 Farad.
The line is designed for 75 % compensation. The Resonance Factor is chosen to be 2. The resonance angle is found to be 45º. The TCSC operation is prohibited from 35º to 55º.

3.1. Single Phase Power System Representation

The single-phase representation of the system without TCSC is shown in Fig. 3. Various blocks of MATLAB simulation are used to design the system. The Active power (True Power) and reactive power (Q) at the receiving end, the load voltage and current are measured without installing TCSC in the system first and then after using TCSC based on two types of pulse generators. The active power at the receiving end is found to be 126.60 MW without any TCSC. The THD analysis of the system is also performed and is shown in the figures. The complete results of the system, like the true power (P), the reactive power(Q), and THD analysis with the two types of pulse generators, are given in Table no 1. [13,14,15]

3.2. System without TCSC

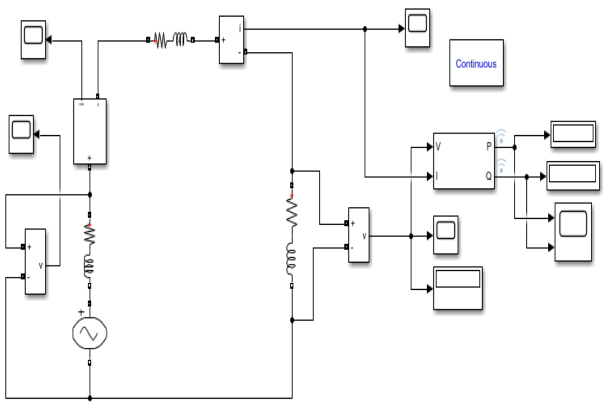

Fig. 3 System without TCSC

3.3. System with TCSC with Type 1 Pulse Generator

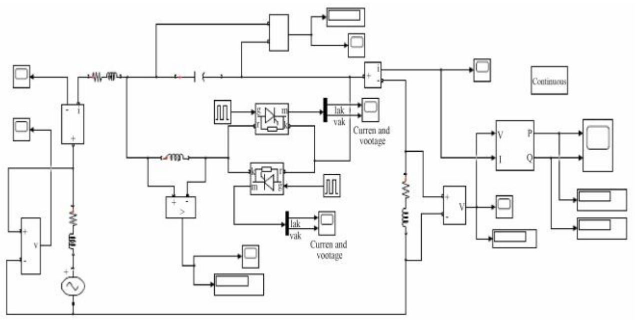

Fig. 4 The system with TCSC based on MATLAB pulse generator block

Next, the same system is implemented using TCSC fired by a MATLAB-based pulse generator. The active power (P)at the receiving end is found to be 180.50 MW for a firing angle of 75º. The active power at the receiving end at a firing angle of 20º is found to be 41 MW which is less than the uncompensated care. This is due to the firing angle of 20º being in inductive mode, and at 75º, it is in the capacitive mode of TCSC. In the inductive mode, the power flow decreases; in the capacitive mode of TCSC, the power flow increases. [16,17,18]

3.4. System with TCSC with Type 2 Novel Pulse Generator

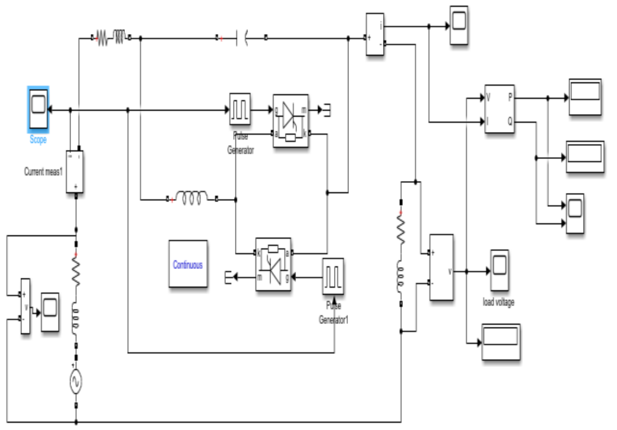

Fig. 5 The system with TCSC based on the novel Power_Pulse Generator

Next, the same system is implemented with the same parameters as TCSC but fired by a novel power pulse generator. The active power was found to be 173 MW for a firing angle of 75 º using this type 2 pulse generator for TCSC.

3.5. Various Waveforms for Single-Phase Representation of the System

3.5.1. Load Voltage Waveform

The load voltage waveform is plotted for three cases without TCSC, with TCSC based on MATLAB pulse generator and novel Power_Pulse generator. The voltage across the load is increased using TCSC based on both the pulse generators and is shown in the waveform fig no 6,7,8.

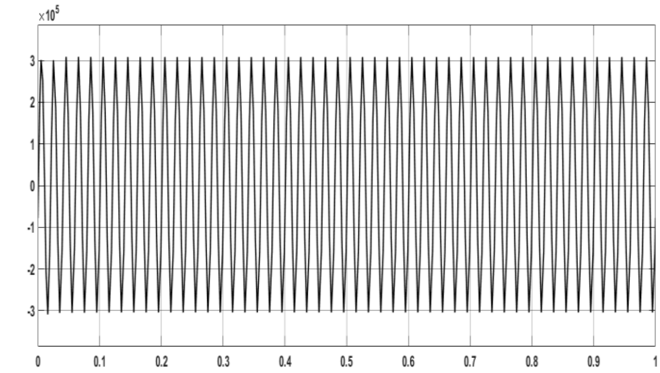

Fig. 6 The waveform of voltage across the load without TCSC

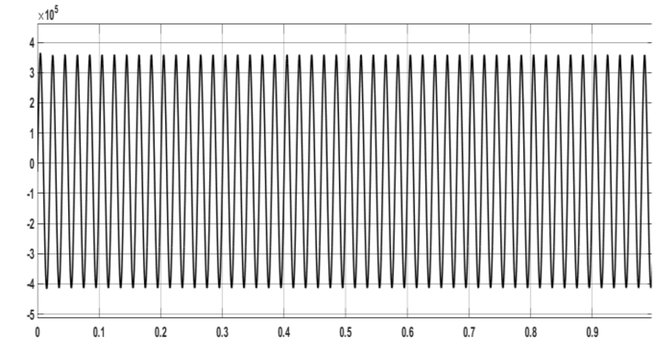

Fig. 7 The waveform of voltage across the load with TCSC based on MATLAB Pulse Generator

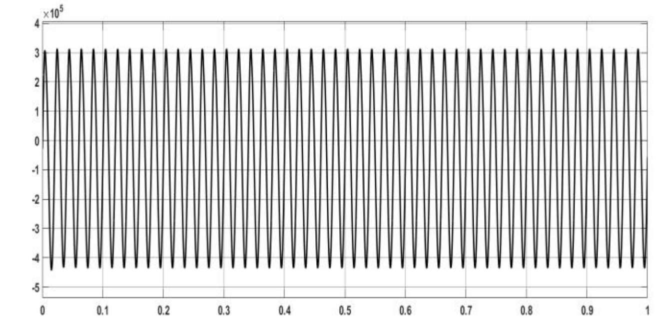

Fig. 8 The waveform of voltage across the load with TCSC based on the novel Power_Pulse Generator

3.5.2. Load Current

The load current is also plotted for the same three cases and is as under. The load current is increased using TCSC based on both pulse generators.

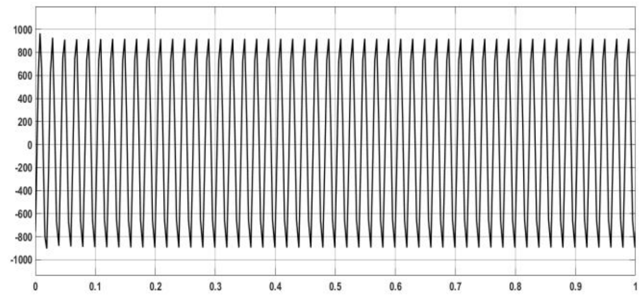

Fig. 9 Load current without TCSC

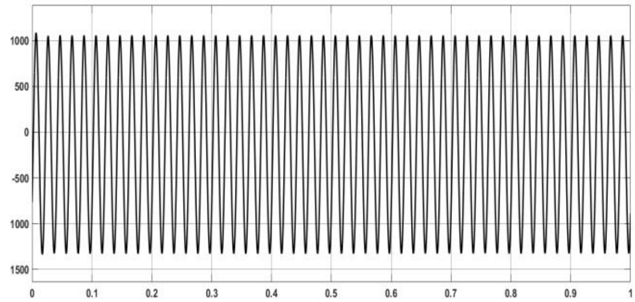

Fig. 10 Load current with TCSC based on MATLAB pulse generator

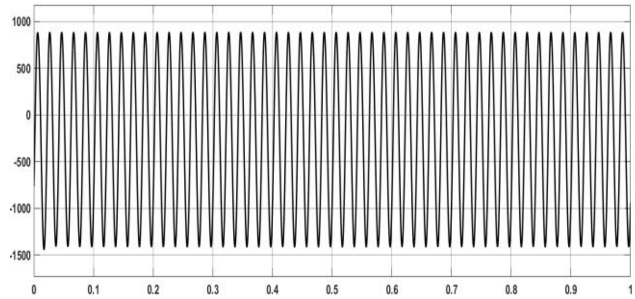

Fig. 11 Load current with TCSC based on novel Power_Pulse Generator

3.5.3. Active Power or True Power (P) and Reactive Power (Q)

The Active power or True Power (P) and reactive power (Q) without TCSC and with TCSC based on two types of pulse generators are given below in Fig. 12,13,14.

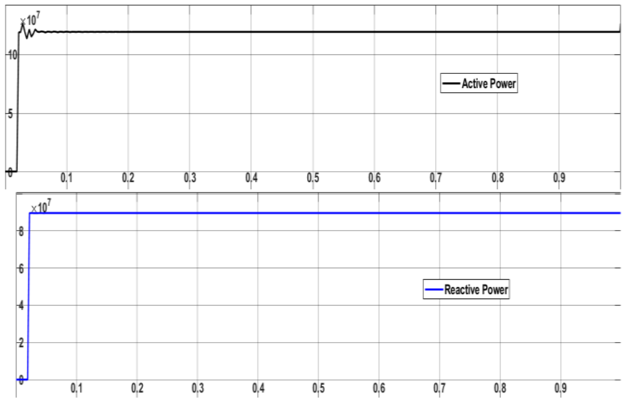

Fig. 12 Active power or true power (P) and Reactive power (Q) without TCSC

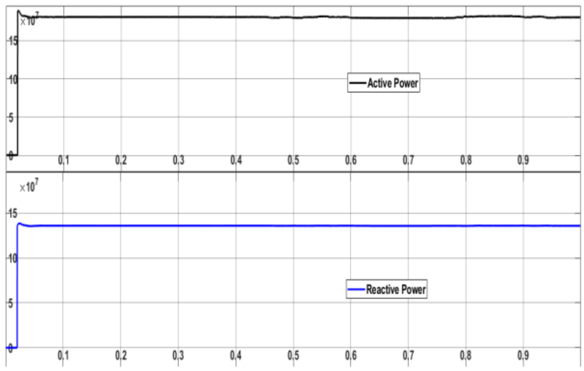

Fig. 13 Active power or true power (P) and Reactive power(Q) with TCSC based on type 1 pulses generator

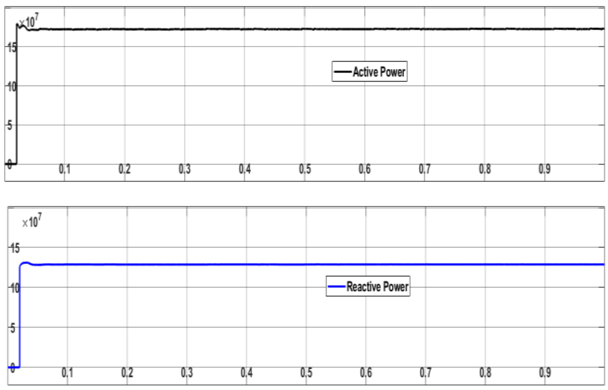

Fig. 14 Active Power or True Power (P) and Reactive power (Q) with TCSC based on type 2 pulse generator

3.5.4. Current and Voltage Waveforms Across Thyristor 1 and Thyristor 2

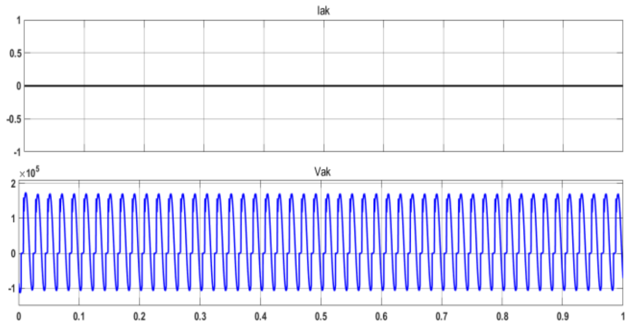

Fig. 15 Current waveform and voltage waveform across thyristor 1 for type 1 pulse generator

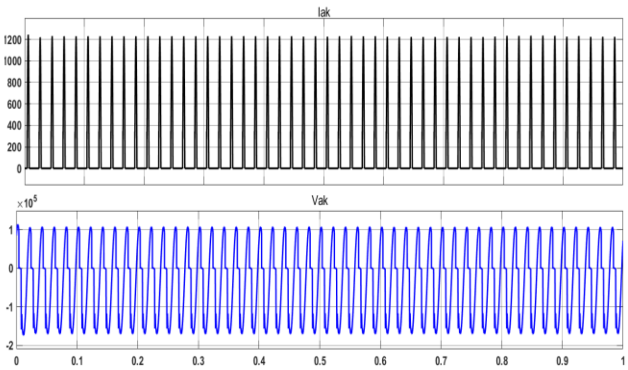

Fig. 16 Current waveform and voltage waveform across thyristor 2 for type 1 pulse generator

3.5.5. Voltage Waveforms Across Inductor and Capacitor for type 1 Pulse Generator

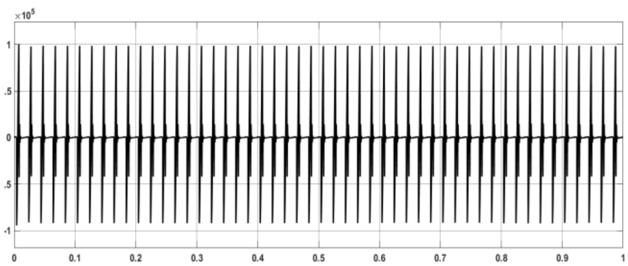

Fig. 17 Voltage waveform across the inductor

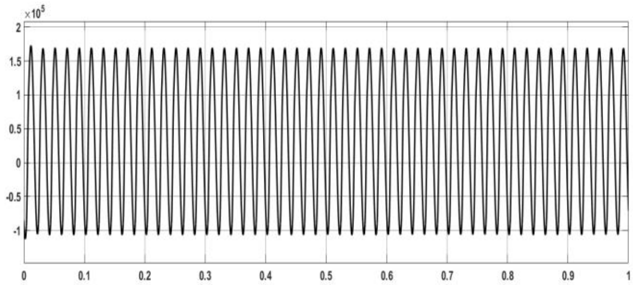

Fig. 18 Voltage waveforms across the capacitor

3.5.6. THD Analysis

It is done using the FFT analysis block of MATLAB simulation.

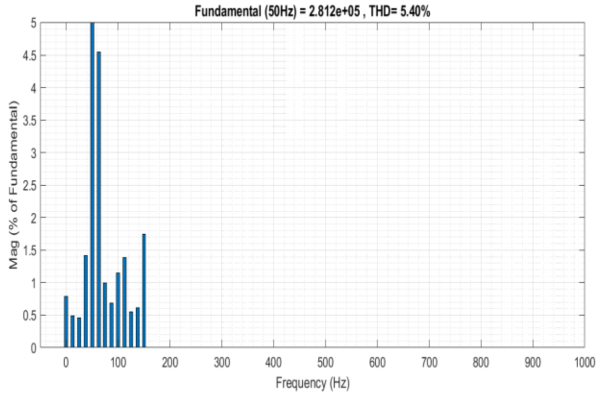

Fig. 19 THD without TCSC

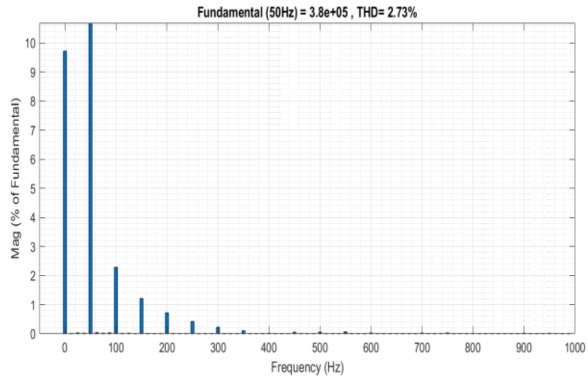

Fig. 20 THD with TCSC based on MATLAB Pulse Generator

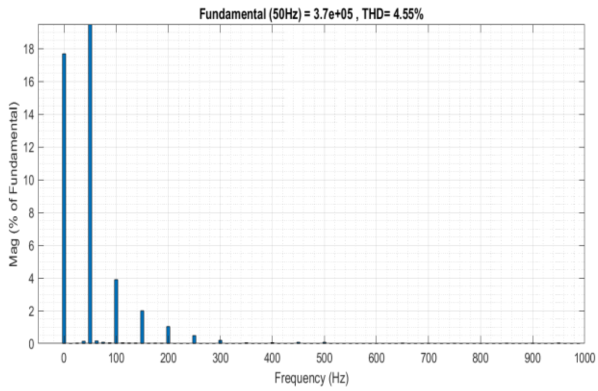

Fig. 21 THD with TCSC based on Power_Pulse Generator

The results of various waveforms from Fig. 6 to Fig. 21 are shown in Table. 1

Table 1. Various results for Single-Phase power system representation

S. No	Parameter	Without TCSC	With TCSC with MATLAB-based PG	With TCSC with Power_Pulse Generator
1	Active Power or True Power (MW)	126.60	180.50	173.00
2	Reactive Power (MVAR)	89.50	135.07	128.90
3	THD voltage (%)	5.40	2.73	4.55

It can be concluded from Table 1 that the Active power or True Power (P) and reactive power(Q) of the system are improved using TCSC. With a MATLAB-based pulse generator, the receiving end has high active power. The THD voltage is also less with that type of Pulse Generator in a single-phase representation of the system. The load current and load voltage are increased using both types of Pulse Generators. The waveforms across the capacitor and inductor can be plotted using the Power_Pulse generator case.

3.5.6. Three-phase Representation of the same Power System

The same system data is now implemented using three-phase blocks of MATLAB simulation. The different cases are systems without TCSC, with TCSC based on two different Pulse generators. The active power or true power (P) and reactive power (Q) are at the receiving end of the system, and THD analysis is done for this representation also. The two Pulse generators successfully increased the active power flow in the system. For this three-phase representation, the load flow analysis of the system is also performed using the Load flow tab of MATLAB. The THD analysis, load flow, active power or true power (P,) reactive power(Q) and other results are given in Table. 2.

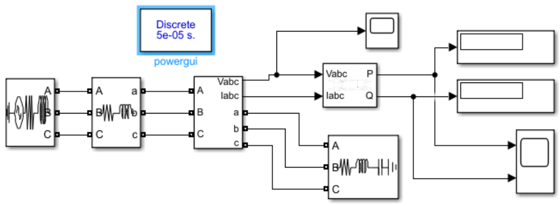

Fig. 22 System without TCSC

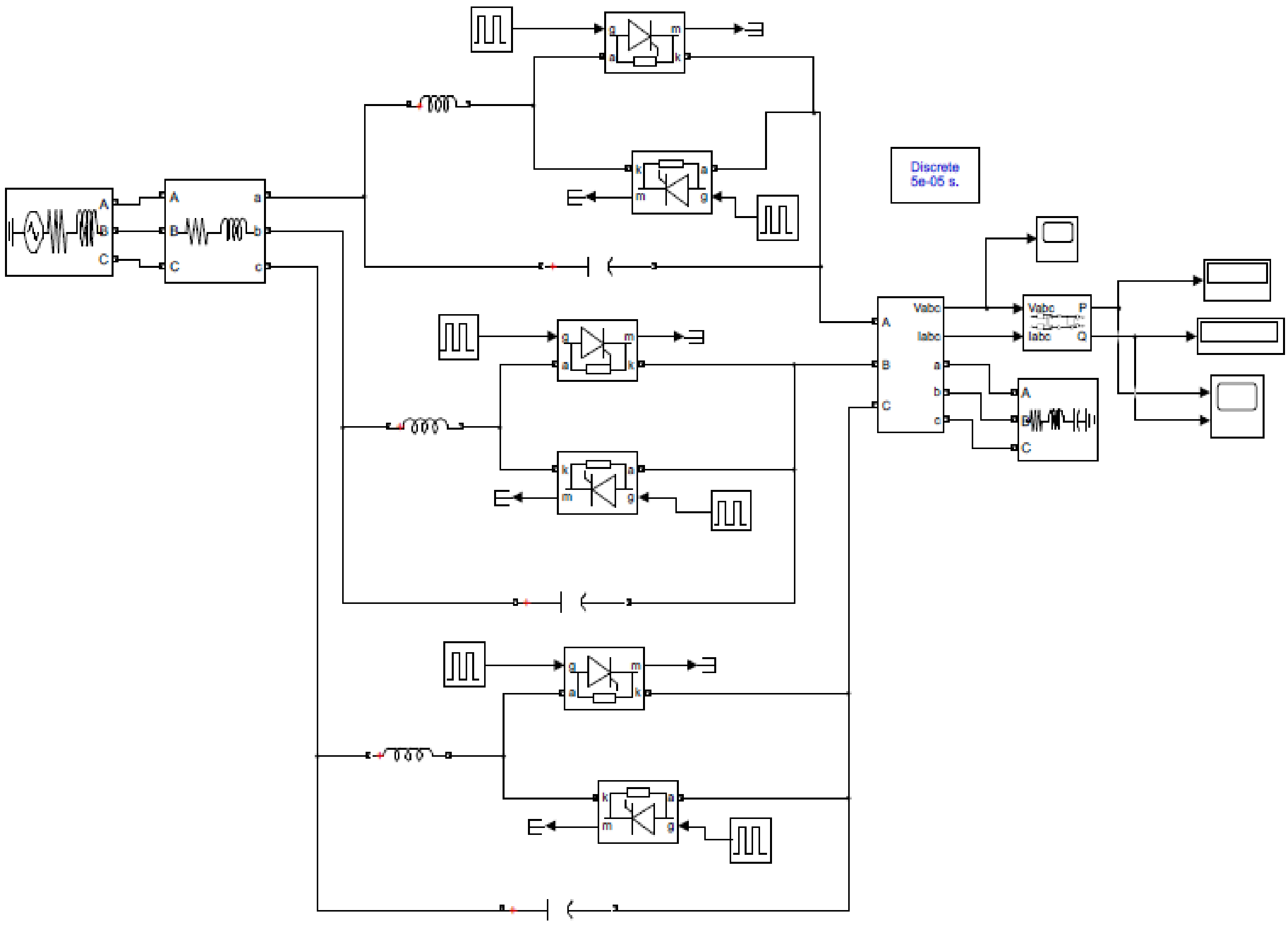

Fig. 23 System with TCSC based on MATLAB Pulse Generator

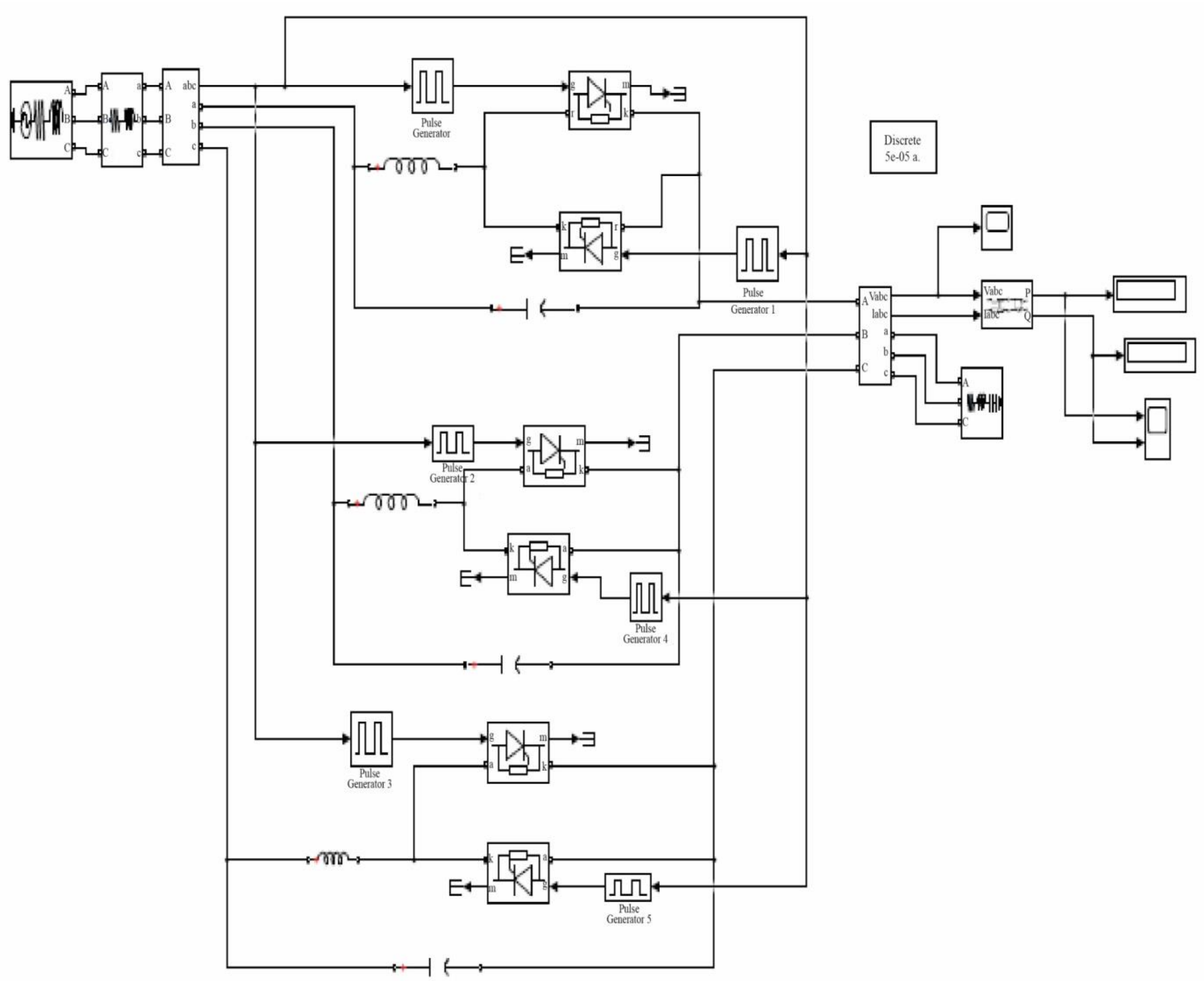

Fig. 24 A system with TCSC based on Novel Power_Pulse Generator

3.5.7. Various Waveforms and Results with the Three-Phase Representation of the System

Active Power or True Power (P) and Reactive power (Q)

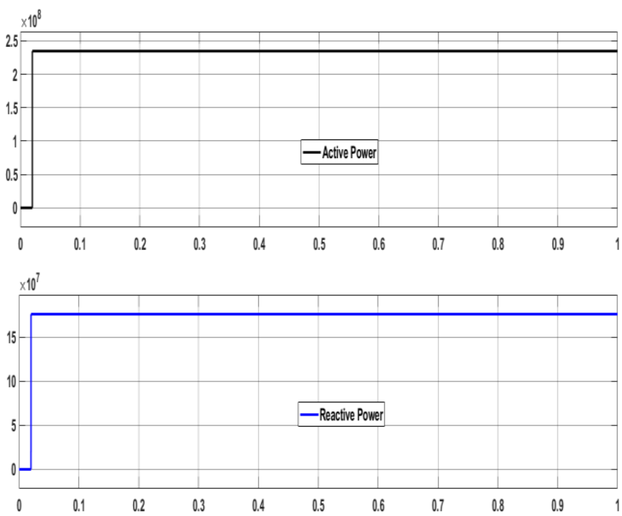

Fig. 25 Active Power or True power (P) and reactive power (Q) without TCSC

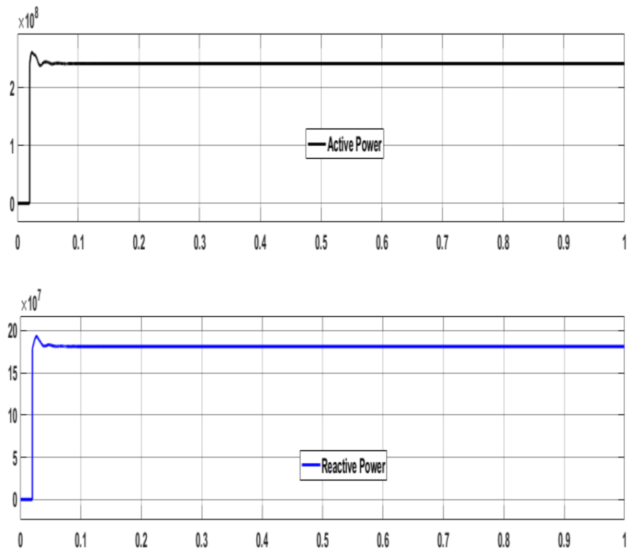

Fig. 26 Active Power or True Power (P) and reactive power(Q) with TCSC based on MATLAB pulse generator

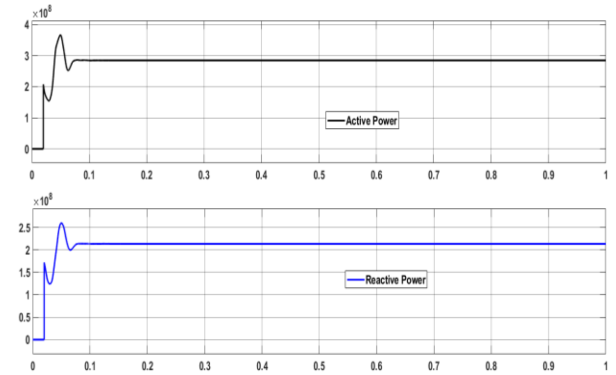

Fig. 27 Active Power or True Power (P) and Reactive Power (Q)with a novel power pulse generator

THD Analysis

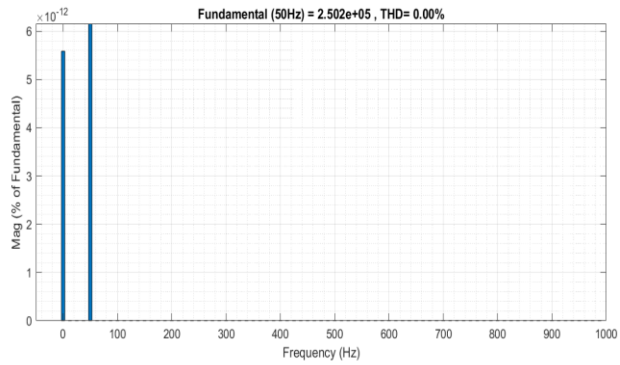

Fig. 28 THD analysis without TCSC

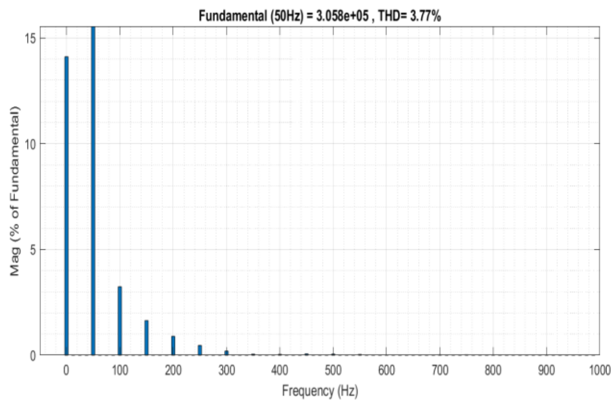

Fig. 29 THD analysis using TCSC based on MATLAB pulse generator

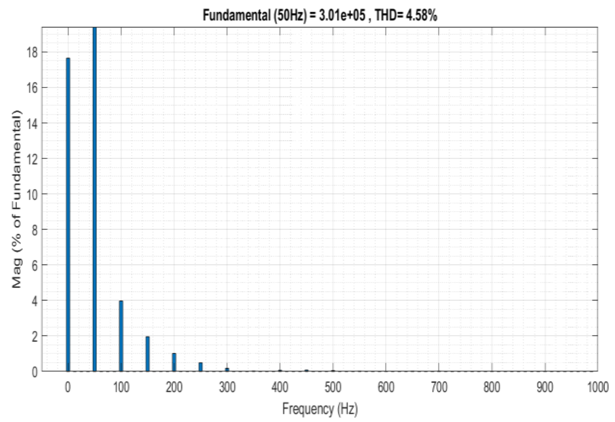

Fig. 30 THD analysis based on novel power pulse generator

The results of various waveforms for fig no 25 to 30 are shown in Table 2

Table 2. Various results obtained with three-phase power system representation

S. No	Parameter	Without TCSC	With TCSC with MATLAB-based PG	With TCSC with Power_Pulse Generator
1	Active Power or True Power (MW)	234.70	241.40	284.40
2	Reactive Power (MVAR)	176.00	181.10	213.30
3	THD voltage (%)	0.00	3.77	4.58
4	Total Generation (MW) by Load Flow Analysis	0.942247	1.3694	1.3694
5	Total Generation (MVAR)by Load Flow Analysis	1.1837	1.2046	1.2046

From Table. 2 for the three-phase representation of the proposed system, it is seen that the active and reactive power is increased using both types of pulse generators. However, using the Novel Power_Pulse generator, there is more active power at the receiving end for the three-phase representation of the system. Thus, this pulse generator brings better results for a three-phase system. But the THD voltage is less in MATLAB-based Pulse generator. Thus, both types of Pulse generators can be used in the system. The total generation (MW, MVAR) obtained by performing the system's load flow analysis using the MATLAB simulation load flow tool is found to be the same for both types of Pulse Generators.

4. Conclusion

In the present work, the system's power flow and quality are improved using TCSC fired by two different types of pulse generators. One is a MATLAB-based pulse generator block, and the other one is a novel power pulse generator. The system performance is improved using both types of pulse generators. In the three-phase representation of the system, the active power is increased more by using the novel Power_pulse generator.

The load flow analysis showed that the total power generation is increased by using TCSC in both types of pulse generators. The load voltage and load currents waveforms for the single-phase representation of the system are plotted, which showed an increase in the values after using TCSC. The waveforms of Active Power or True Power (P) waveforms and reactive power (Q) flow without and with TCSC are plotted using two pulse generators.

The voltage across the capacitor and inductor is also plotted. The system's power quality is also improved here due to the reactive power contribution from TCSC.TCSC also improved the transient stability and damping of the system by providing variable reactance to the system based on firing angle control by pulse generators. The power transmission operators can use the current transmission system to their maximum thermal capacity and available transfer capacity using a power electronics-based device TCSC.

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