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Soft computing Applications to power systems

Comparison of Numerical Techniques Applied to Shunt Connected Reactive Power Control Device

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Abstract: *This paper presents the application of different numerical techniques to model one of the FACTS controlled device TCR (Thyristor controlled reactor) for power enhancement in transmission lines with the help of power electronics concepts. The results are verified with Saber RD student edition for circuit simulation.*

***Keywords*:** Numerical Techniques, TCR, FACTS devices

I. INTRODUCTION

By definition, capacitors generate and reactors (inductors) absorb reactive power when connected to an ac power source. They have been used with mechanical switches for (coarsely) controlled var generation and absorption since the early days of ac power transmission. Continuously variable var generation or absorption for dynamic system compensation was originally provided by over-or under excited rotating synchronous machines and later, by saturating reactors in conjunction with fixed capacitors [2]. Since the early 1970s high power, line-commutated thyristors in conjunction with capacitors and reactors have been employed in various circuit configurations to produce variable reactive output. These in effect provide a variable shunt impedance by synchronously switching shunt capacitors and /or reactors "in" and "out" of the network. Using appropriate switch control, the var output can be controlled continuously from maximum capacitive to maximum inductive output at a given bus voltage. More recently gate turn-off thyristors and other power semiconductors with internal turn-off capability have been used in switching converter circuits to generate and absorb reactive power without the use of the ac capacitors or reactors. These perform as ideal synchronous compensators (condensers), in which the magnitude of the internally generated ac voltage is varied to control the var output. All of the different semiconductor power circuits, with their internal control enabling them to produce var output proportional to an input reference, are collectively termed by the joint IEEE and CIGRE definition, static var generators (SVC). Thus, a static var compensator (SVC) is, by the IEEE CIGRE co-definition, a static var generator whose output is varied so as to maintain or control specific parameters (e.g., voltage, frequency) of the electric power system. A TCR is one of the most important building blocks of thyristor-based SVCs. Although it can be used alone, it is most often employed in conjunction with fixed or thyristor-switched capacitors to provide rapid, continuous control of reactive power over the entire selected lagging-to-leading range [2].

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II. OBJECTIVES

Objectives of this paper are:

- To motivate the study of numerical methods through discussion of engineering applications.
- To determine the performance of impedance type var generator-the thyristor controlled reactor by applying different numerical methods.
- To verify the program results using saber simulation tool
- To compare the simulations results with GNU plots obtained from code blocks using C as coding language
- To verify the decrease in sinusoidal property of TCR current and increase in transmittable power in transmission line.

III. NUMERICAL METHODS

Calculus is a branch of mathematics involving or leading to calculations dealing with continuously varying functions
Calculus is a subject that falls into two parts:

- Differential calculus (or differentiation)
- Integral calculus (or integration)

The equations which are composed of an unknown function and its derivative are called differential equations. When the function involves one independent variable, the equation is called as ordinary differential equation. Differential equations are classified as their order. If the highest derivative is a first derivative, then it is a first –order equation. A second order equation would include a second derivative.

A. Different methods to solve differential equation

In this section, a brief review of various numerical techniques commonly employed in the stability study is presented. To solve a differential equation, the numerical techniques employed are [1]

1. Forward Euler's Method
2. Backward Euler's Method
3. R-K 4th Order Method

Given a differential equation,

$$\frac{dy}{dx} = f(x,t) \qquad (1)$$

1. Forward Euler method:

The algorithm is given by:

$$X_{n+1} = X_n + f(x_n, t_n)h \qquad (2)$$

Where 'h' is the step size.

For an RL series circuit with v(t) as the source voltage.

$$\frac{dy}{dx} = \frac{di_L}{dt} = \left(\frac{v - i_L R}{L}\right) \qquad (3)$$

For the nth interval

i_l (4) $n) + Kh$

Where $K = \frac{V_n}{L} - \frac{Ri_{L(n)}}{L}$

2. Backward Euler Method:

The algorithm is given by:

$$X_{n+1} = X_n + \left(X_{n+1,} t_{n+1}\right)h \qquad (5)$$

For an RL series circuit with v(t) as the source voltage,

$$\frac{dy}{dx} = \frac{di_L}{dt} = \left(\frac{v - i_L R}{L}\right) \qquad (6)$$

For the nth interval, $\boldsymbol{i_{L(n+1)}} = \frac{\boldsymbol{i_{L(n)}L + vh}}{\boldsymbol{L + Rh}}$ (7) (3.2.3)

3. Runge –Kutta(R-K) 4th order approximation Method

The value of *x* at the end of the interval is given as:

$$x_{n+1} = x_n + \frac{(k_1 + 2k_2 + 2k_3 + k_4)}{6} \qquad (8)$$

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Where,

$$k_1 = f(x_1, t_1)\Delta t$$
$$k_2 = f[(x_1 + 0.5k_1), (t_1 + 0.5\Delta t)]\Delta t$$
$$k_3 = f[(x_1 + 0.5k_2), (t_1 + 0.5\Delta t)]\Delta t$$
$$k_4 = f[(x_n + hk_3), (t_n + h)]$$

It is to be noted that R-K method employs slope of the curve at predetermined points within the interval to calculate the value of *x* at the end of the interval.

I. MODELING OF TCR

With increased power transfer, transient and dynamic stability is of increasing importance for secure operation of power systems. A power electronic based system and other static equipment that provides control of one or more transmission parameters are called FACTS controllers.

A basic single-phase TCR comprises an anti-parallel–connected pair of thyristors valves, *T*1 and *T*2, in series with a linear air-core reactor, as illustrated in Fig.1. The anti-parallel–connected thyristor pair acts like a bidirectional switch, with thyristor valve *T*1 conducting in positive half-cycles and thyristor valve *T*2 conducting in negative half-cycles of the supply voltage. The firing angle of the thyristors is measured from the zero crossing of the voltage appearing across its terminals.

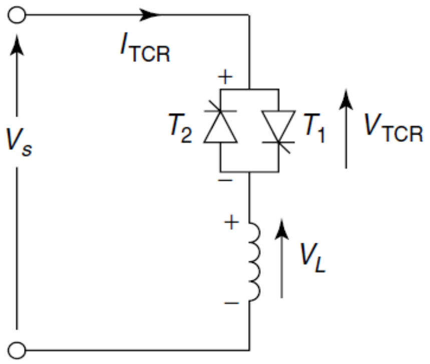

Fig.1 A TCR

For modeling and analysis of TCR, the most practical available method is time domain simulation in which the nonlinear differential equations are solved using numerical method considering the time step. The main aim of these devices is to decrease the line reactance so that the power transmitted to the load is increased.

$$\frac{di_{(TCR)}}{dt} = \frac{V_S - iR}{L} \quad (9)$$

With $v(t) = v_m \sin(\omega t)$ as sine function, R=3Ω, L=0.01H and with firing angles, 90°,110°,150° Euler's forward method is applied to the above differential equation and the results obtained are analyzed.

The basic equation of power transmission is given by:

$$P = \frac{V_1 V_2}{X} \sin \delta \quad (10)$$

Where, V_1 and V_2 are voltages at both ends, δ is the angle between V_1 and V_2, X is the total line reactance.

The controllable range of the TCR firing angle, α, extends from 90° to 180°. A firing angle of 90° results in full thyristor conduction with a continuous sinusoidal current flow in the TCR. As firing angle is increased above 90°, non-sinusoidal current flows and magnitude of fundamental frequency of current reduces. This is equivalent to increase in the inductance value which in turn decreases the line reactance thereby reducing its capacity to draw reactive power and hence enhance the transmittable power.

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I. RESULTS

As the firing angle is varied from 90° to close to 180°, the current flows in the form of discontinuous pulses symmetrically located in the positive and negative half-cycles. The results are displayed in fig. 2, 4 and 6 below for different firing angles. The results are verified with Saber RD student edition for circuit simulation shown in fig. 3, 5 and 7 below for different firing angles

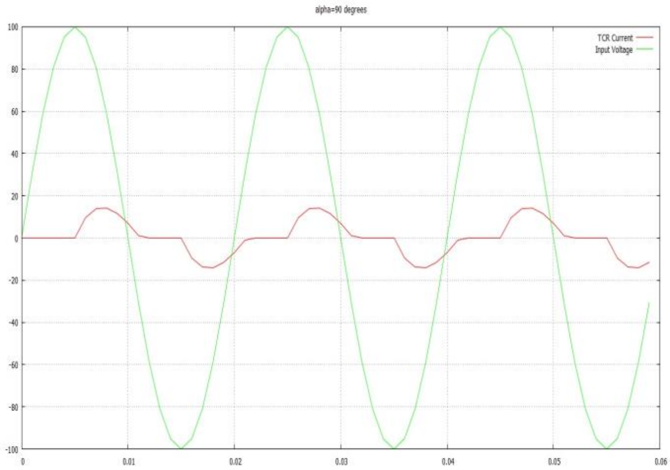

Fig.2 GNU plots of voltage and current for α=90° in a TCR

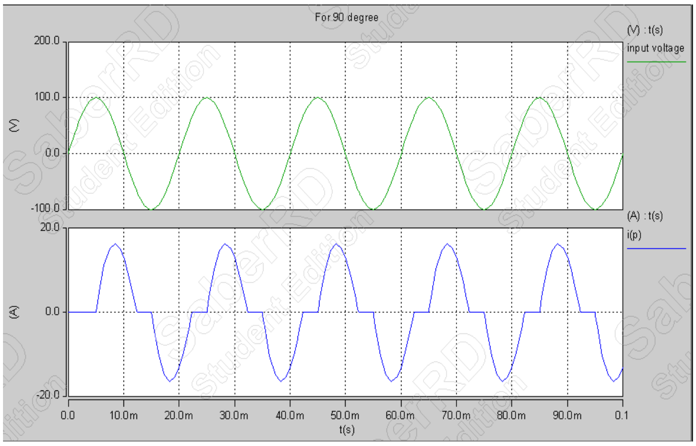

Fig.3 Voltage and current for α=90° in a TCR

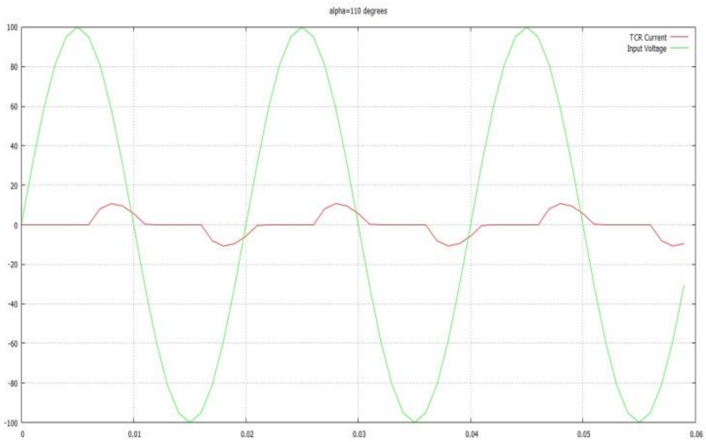

Fig.4 GNU plots of voltage and current for α=110° in a TCR

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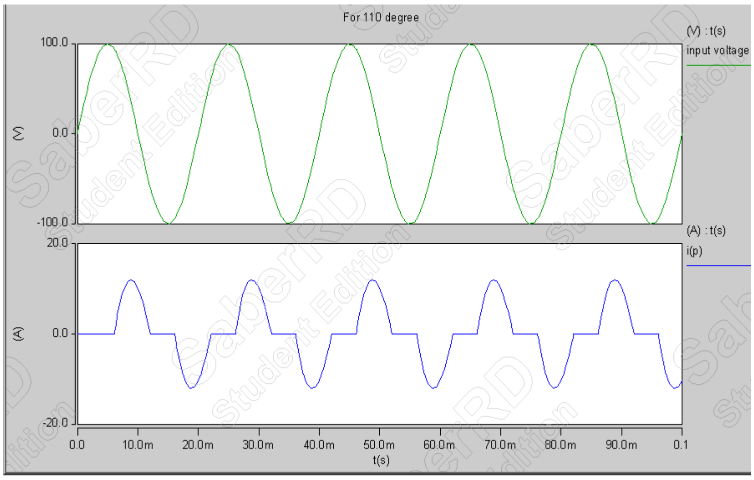

Fig.5 Voltage and current for α=110° in a TCR

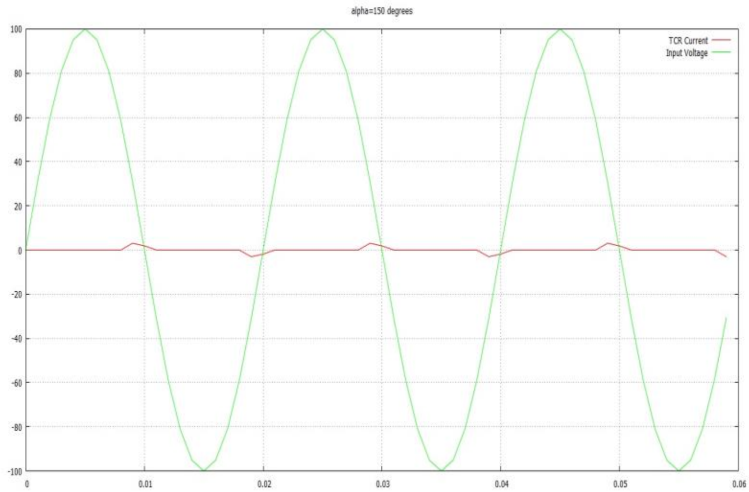

Fig.6 GNU plots of voltage and current for α=150° in a TCR

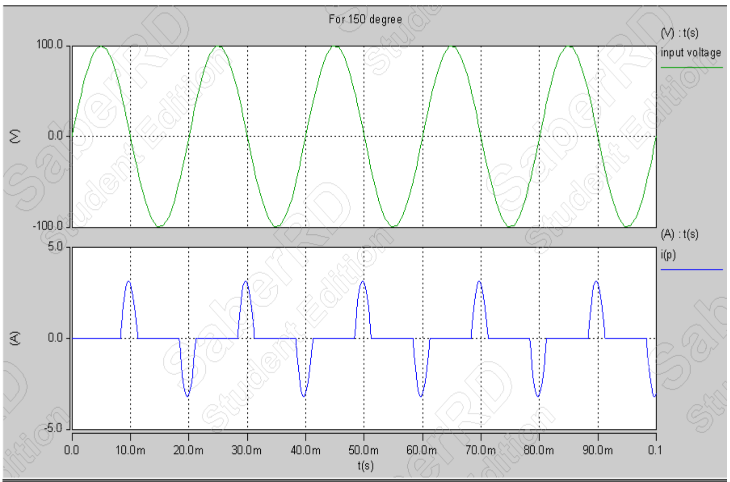

Fig.7 Voltage and current for α=150° in a TCR

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IV. CONCLUSION

- It is evident that the current in the reactor can be varied continuously by the method of delay angle control from maximum $\alpha = \frac{\pi}{2}$ (to minimum $\alpha = \pi$)
- Increasing the value of firing above $\frac{\pi}{2}$ causes the TCR current waveform to become non-sinusoidal, with its fundamental frequency component reducing in magnitude. This, in turn, is equivalent to an increase in the reactor, reducing its ability to draw reactive power from the network at the point of connection.

REFERENCES

[1] Dr. K.N. Shubhanga, *"State-space Modelling and Numerical Integration Techniques: An Introduction"*, July 20, 2014.
[2] R.MohanMathur and Rajiv.K.Verma, *Thyristor based FACTS controllers for electrical transmission systems*, Wiley India Pvt. Ltd.
[3] Narain G. Hingorani and Laszlo Gyugyi, *"Understanding FACTS-concepts and technology of FACTS"*, 2013.
[4] Enrique Acha , "*FACTS-Modelling and Simulation in power Networks",2012*
[5] A.M. Padma Reddy, *"Systematic approach to Data Structure Using C"*, Revised Edition, 2007

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