Application of EMTP Simulation Softwar for Implementation of a Phase Shift Correction

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ABSTRACT

This paper deals with the definition and simulation of the control strategy of the closed-loop phase shift correction method using Electromagnetic Transients Program (EMTP). In this case two different logic methods (phase detector) are implemented by using the facility provided in Transient Analysis of Control System (TACS) in order to measure the phase angle displacement between two vector signals. In addition, another logic method is defined in TACS to generate a new vector signal that is used for implementation of the phase shift correction method. The simulation results for this method are presented and the results are almost symmetrical and acceptable comparing to the theory.

1. Introduction

In general, the elements of some circuit such as in passive filters add some phase shift displacement to the output voltage. This phase shift displacement between input and output voltages of the delay circuit (filter) could be either lagging or leading depends on the characteristics of the filter and the load. In many applications this phase shift displacement is not acceptable such as in a Flexible AC Transmission Systems (FACTS) [1-4]. Therefore, it is necessary in such applications to build a closed loop control phase shift correction system in order to correct (compensate) this phase shift displacement but without changing the magnitude of the original vector (signal).

In Electromagnetic Transients Program (EMTP, ATP version) users should use the Transient Analysis of Control System (TACS) facility in order to build such control system [5-6]. However, in TACS the user can only represent (measure) the instantaneous waveforms of a node voltage and a branch current. Therefore, in order to design a closed loop control phase shift correction system in TACS it is necessary first to build a logic circuit which can measure the phase angle displacement (φ) between the input and output voltages of the filter and then build a complete closed loop control system using TACS facility.

2. Theory of a phase shift correction system

Figure 1 shows a block diagram of a closed-loop control phase shift correction system. The target from this control system is to keep the angle (φ) between the waveforms (signal vectors) ($\overline{A}$) and ($\overline{B}$) equal to zero at steady state without changing their magnitude, i.e. |A|=|B|. The operation of figure 1 is as follows: First, the displacement angle (φ') between ($\overline{A}$) and ($\overline{B}$) is measured by a logic circuit (1) (phase detector). Second, the measured angle (φ') is passed through a Proportional-Integral (PI) controller. Third, the output from PI controller (φ) is used to generate a vector voltage (V_φ) using a logic circuit (2). The vector (V_φ) should have a magnitude of $2V_p\sin(\varphi/2)$ and an angle of in ($\varphi/2+\pi/2$) with respect to vector $\overline{A}$ as shown in equation (1). This can be seen in the vector diagram shown in Figure 2.

$$V_j = 2A\sin\frac{j}{2}\angle\frac{j}{2}+\frac{p}{2} \quad (1)$$

Or,

$$V_j = 2A\sin\frac{j}{2} * \left[\cos\left(\frac{p}{2}+\frac{j}{2}\right) \pm j\sin\left(\frac{p}{2}+\frac{j}{2}\right)\right] \quad (2)$$

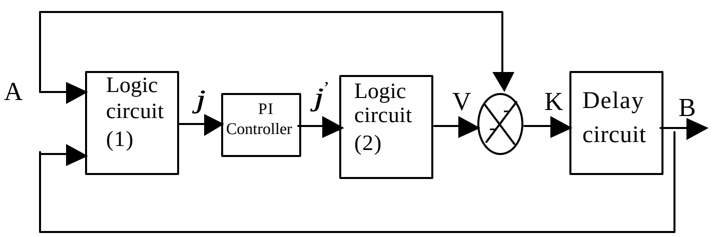

Figure 1: A block diagram for a phase shift correction method.

This signal vector is then added to the original signal vector (A) to produce a new vector signal (K) as following:

$$\bar{K} = \bar{A} + \bar{V}_j \quad (3)$$

Thus, if the magnitude of the signal vectors $|\bar{K}|$ then it can be found as follows:

$$|\bar{K}| = \sqrt{\left[A+2A\sin\frac{j}{2}\cos\left(\frac{p}{2}+\frac{j}{2}\right)\right]^2 + \left[2A\sin\frac{j}{2}\sin\left(\frac{p}{2}+\frac{j}{2}\right)\right]^2} \quad (4)$$

$$|\bar{K}| = \sqrt{\begin{array}{l} A^2+4A^2\sin^2\frac{j}{2}\cos^2\left(\frac{p}{2}+\frac{j}{2}\right)+ \\ 4A^2\sin\frac{j}{2}\cos\left(\frac{p}{2}+\frac{j}{2}\right)+ \\ 4A^2\sin^2\frac{j}{2}\sin^2\left(\frac{p}{2}+\frac{j}{2}\right) \end{array}} \quad (5)$$

$$|\bar{K}| = \sqrt{A^2+4A^2\sin^2\frac{j}{2} - 4A^2\sin^2\frac{j}{2}} = \sqrt{A^2} = A \quad (6)$$

Hence the phase angle of $\bar{K}$ is:

$$j_K = \tan^{-1}\frac{\pm 2A\sin\frac{j}{2}\sin\left(\frac{p}{2}+\frac{j}{2}\right)}{A+2A\sin\frac{j}{2}\cos\left(\frac{p}{2}+\frac{j}{2}\right)} \quad (7)$$

$$j_K = \tan^{-1}\frac{\pm 2\sin\frac{j}{2}\cos\frac{j}{2}}{1-2\sin^2\frac{j}{2}} \quad (8)$$

$$j_K = \tan^{-1}\frac{\pm\sin j}{\cos^2\frac{j}{2}-\sin^2\frac{j}{2}} = \tan^{-1}\frac{\pm\sin j}{\cos j} = \pm j \quad (9)$$

	Intial condition	Steady state
j	Phase shift angle	zero
j'	zero	Phase shift angle

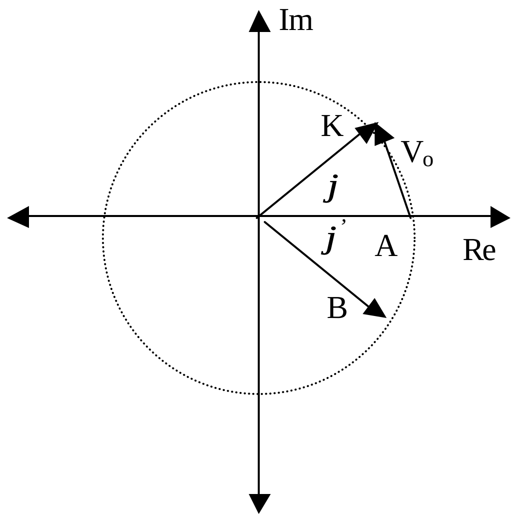

Figure 2: A vector diagram for a phase shift correction method.

Therefore, the selected definition for phasor vector $\overline{K}$ *ensures* that the resultant phasor signal $\overline{K}$ has the same magnitude as the signal vector $\overline{A}$, but its phase angle is different from that of $\overline{A}$ by an angle j at steady state condition. In practical terms, this means

that phase shifting is achieved without any unintentional magnitude change in the controller terminal signal. Therefore, this will lead to the fact that the vectors ($\overline{A}$) and ($\overline{B}$) will be in phase because φ' is equal to zero at steady state condition as shown in figure 2.

3. Implementation of a phase shift correction system in TACS

Since the phase angle (φ') can't be directly represented (measured) in TACS, it was decided to design a logic circuit to measure this angle by using the FORTRAN expressions and the TACS devices facility. Therefore, two different TACS logic circuits has been designed to measure this angle as shown in figures 3 and 4.

As it has been described above, it was decided to design another logic circuit to generate a vector ($V_φ$). However, from equation (2) it can be seen that this equation contains an imaginary part in which it can't be represented in TACS. Nevertheless, to solve this problem it was decided to represent an the imaginary part of this equation as a differentiator as presented below:

$$V_j = 2A\sin\frac{j}{2}\cos\left(\frac{p}{2}+\frac{j}{2}\right)\pm \frac{d}{dt}\left[2A\sin\frac{j}{2}\sin\left(\frac{p}{2}+\frac{j}{2}\right)\right] \qquad (10)$$

This solution has been tested separately in TACS and the results were acceptable comparing to the mathematical solutions.

Figures 3 and 4 show the complete flow chart of two different methods for the phase shift correction system in TACS. However, it was found that in both methods the control action was disconnected when the error signal (φ') reaches zero degree and thus the error jumps back to its original value which switches the controller on again and makes the controller output (φ') equal to (2φ') and then (3φ') …. etc as shown in figure 5. It was found that, this problem appears due to the switching action in the logic circuit (2) from one condition (lagging) to another condition (leading) when the error signal tries to stable at zero degree. This switching action from one condition to another causes in changing the magnitude and the angle of the vector ($\overline{K}$) and thus forces the controller to start again. To solve this problem it was decided to assume that the error signal (φ') is equal to zero when it reaches approximately zero degree (0.3°) so that to overcome the switching action from one condition to another. This solution has been tested in both logic methods for different types of phase shift circuits in TACS and the results were acceptable comparing to the theory as shown in figures 6 to 7.

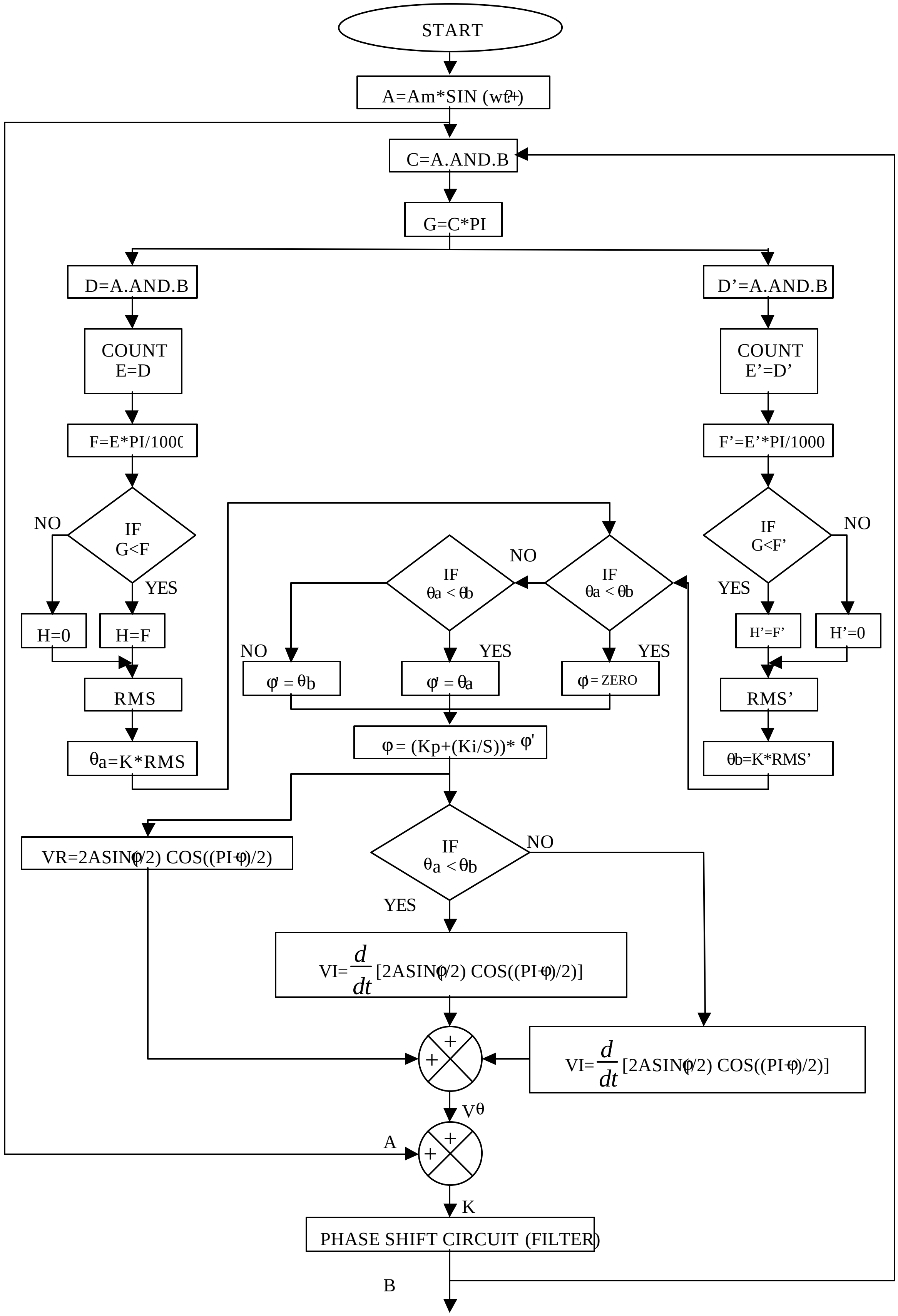

Figure 3: The flow chart of the phase shift correction system in TACS (Method 1)

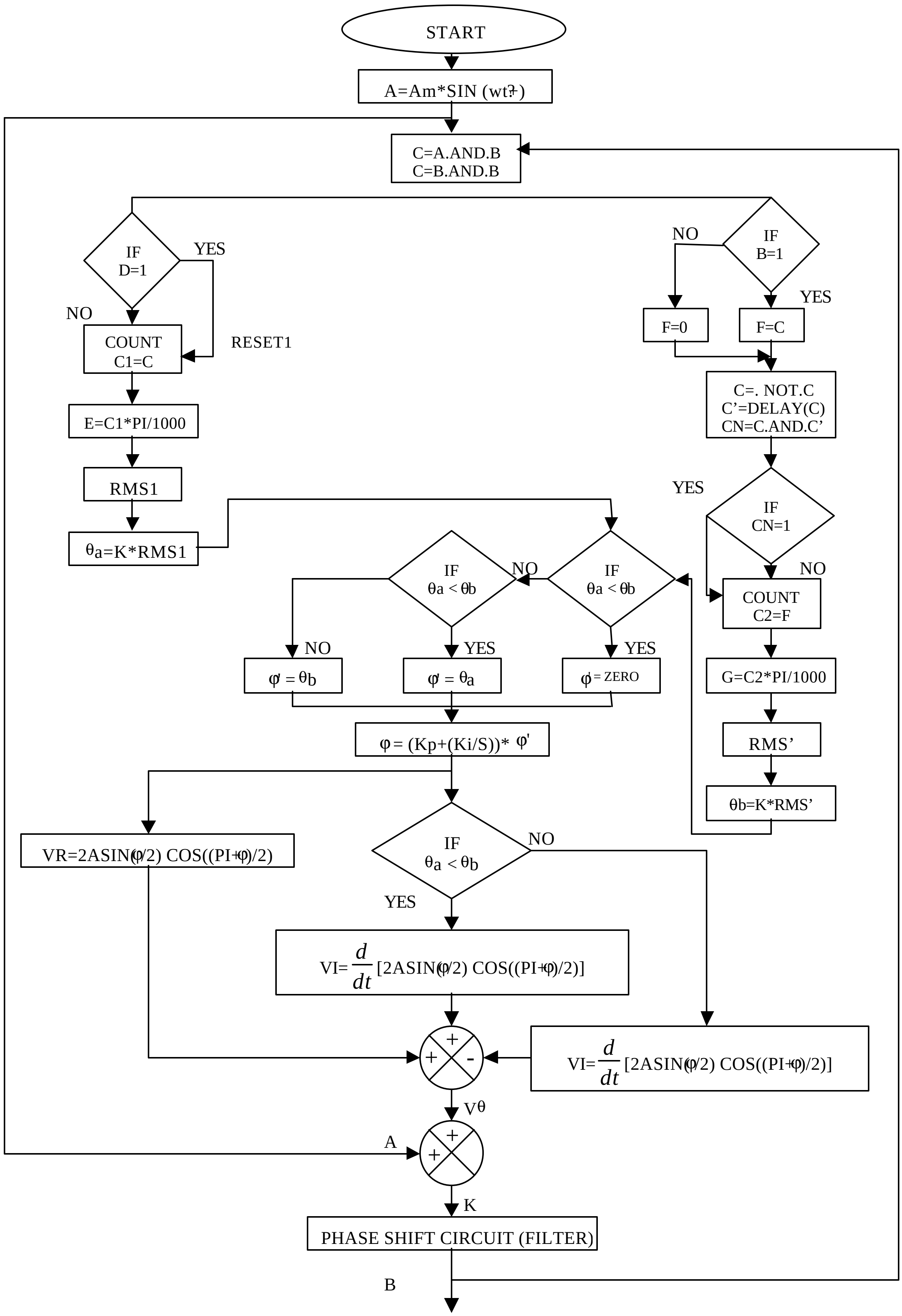

Figure 4: The flow chart of the phase shift correction system in TACS (Method 2)

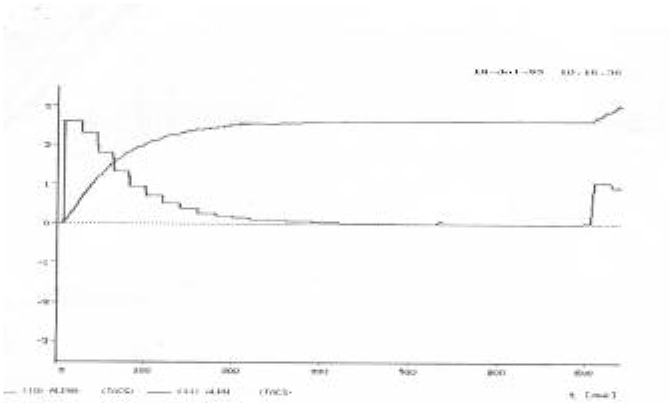

Figure 5: The input and the output signals From the PI controller block.

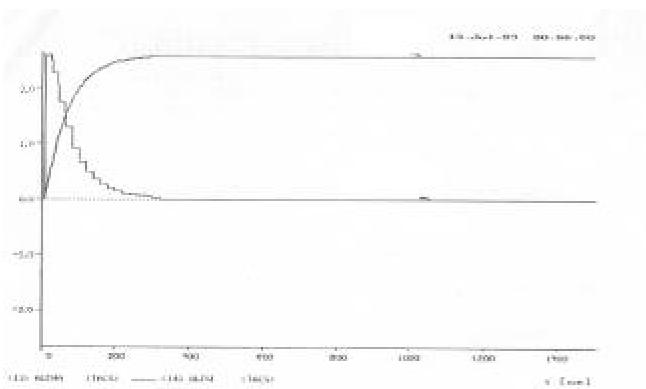

Figure 6: The input and the output signals from the PI controller block.

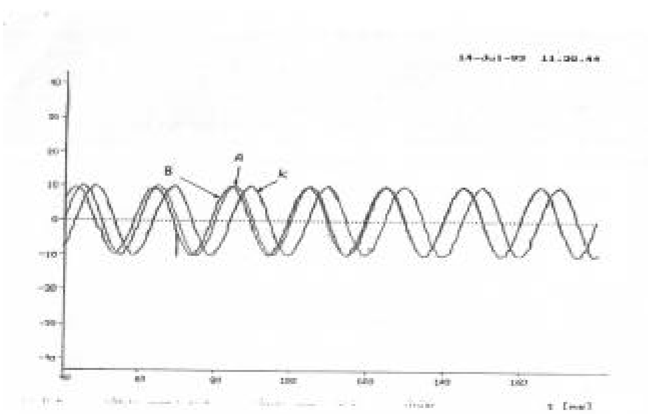

Figure 7: The waveforms of the vectors ($\overline{A}$), ($\overline{B}$) and ($\overline{K}$) when the phase shift correction method is applied.

4. Conclusion

The closed loop control phase shift correction system has been implemented in EMTP. In this case two different logic methods (phase detector) have been implemented in TACS to measure the phase angle displacement between two vector signals. It was found that, the simulation results from both types of phase detector are almost symmetrical and acceptable comparing to the theory. In addition, another logic method has been defined in TACS to generate a new vector signal. This new signal has been used for implementation of the phase shift correction method. The simulation results for this method has been presented and the results are almost symmetrical and acceptable.

5. References

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