Critical clearing time evaluation of power system with UPFC by energetic method

B. Boussahoua[1] and M. Boudour[1]
[1]Faculty of Electrical Engineering, USTHB, Algiers, Algeria
El-Alia BP. N°32 Bab Ezzouar 16111,
Phone:+213 21 20 76 69, fax:+213 21 20 76 69, e-mail: **bbouziane72@yahoo.com, mboudour@ieee.org**

1. Brief introduction

In practice, the CCT can be obtained in one of two ways: by trial and error analysis of system post disturbance equations [1,2] or by integrating fault-on equations and checking the value of Lyapunov energy function until it reaches a previously determined critical level [3]. For the first approach, many integration processes are necessary. But, for the second approach we can evaluate the CCT in just one integration process. The major problem for the second approach is to find an analytical energy function which considers a precise model of generator and the effect of new Flexible AC Transmission System (FACTS) devices added to improve the transient behaviour of power system like UPFC.

In this paper, we deal with the construction of such function. Each generator is represented by the six order model. This later takes in consideration the regulation systems and the stabilisation devices. The insertion of UPFC is discussed in this paper. An analytical energy function is presented for system with UPFC. The PEBS proposed in literature [3] is used to evaluate the CCT.

The IEEE 3-machine 9-bus [4] test systems are used to illustrate the proposed approach for CCT evaluation. A generalised software tool is elaborated and simulations performed through give promising results.

Key words: Power System, Transient Stability, Energy Function, Unified Power Flow Controller.

2. System model with UPFC

Most of works on the transient energy function method are focused to determine the first swing stability limit of power system without any FACTS devices [5]. However, FACTS devices are now increaseally used in actual power system to improve the transient stability behaviour.
All generators are modelled by the sixth order model with speed and excitation governor [6]. The UPFC base model and the UPFC injection model are presented in figure 1 and figure 2.

U_T magnitude of the injected voltage

φ_T angle of the injected voltage

I_q reactive parallel branch current

I_T depends on active power injected in series branch

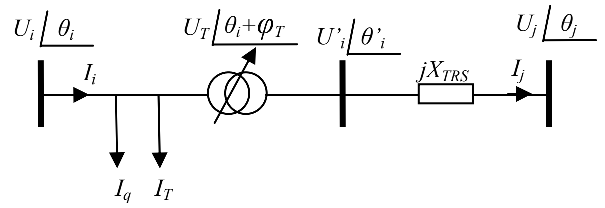

Fig.1. UPFC base model

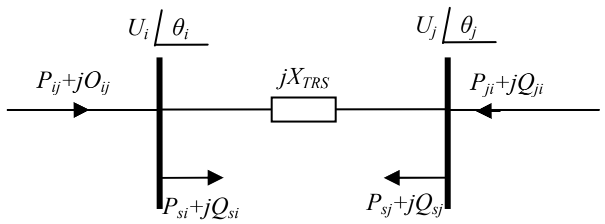

Fig.2. UPFC injection model

3. Energy function of system with UPFC

To construct Lyapunov functions, the first integral of motion, which is the sum of kinetic and potential energies has provided the best result [6]. Reference [5] gives an expression for an energy function of system with detailed model.

$$V_T(t_0,t) = V_K(t_0,t) + V_P(t_0,t) \quad (8)$$

For system with UPFC, we must add a term to represent the effect of UPFC and the transient energy function takes this expression:

$$V_T(t_0,t) = V_K(t_0,t) + V_P(t_0,t) + V_{UPFC} \quad (9)$$

In the case of UPFC, the energy function is equal to the total sum of the reactive powers [6]

$$V_{UPFC} = Q_i + Q_j \quad (10)$$

4. CCT evaluation by PEBS approach

In our study, the Structure Preserving Energy Function is considered. For this case, the CCT can be determined as the maximum value of an energy function along the system's fault-on trajectory. In this way, the evaluation of CCT for a particular fault is limited to just one fault-on numerical integration. The flowchart presented in figure 3 describes a procedure to CCT evaluation in the case of SPEF and the use of PEBS method [9].

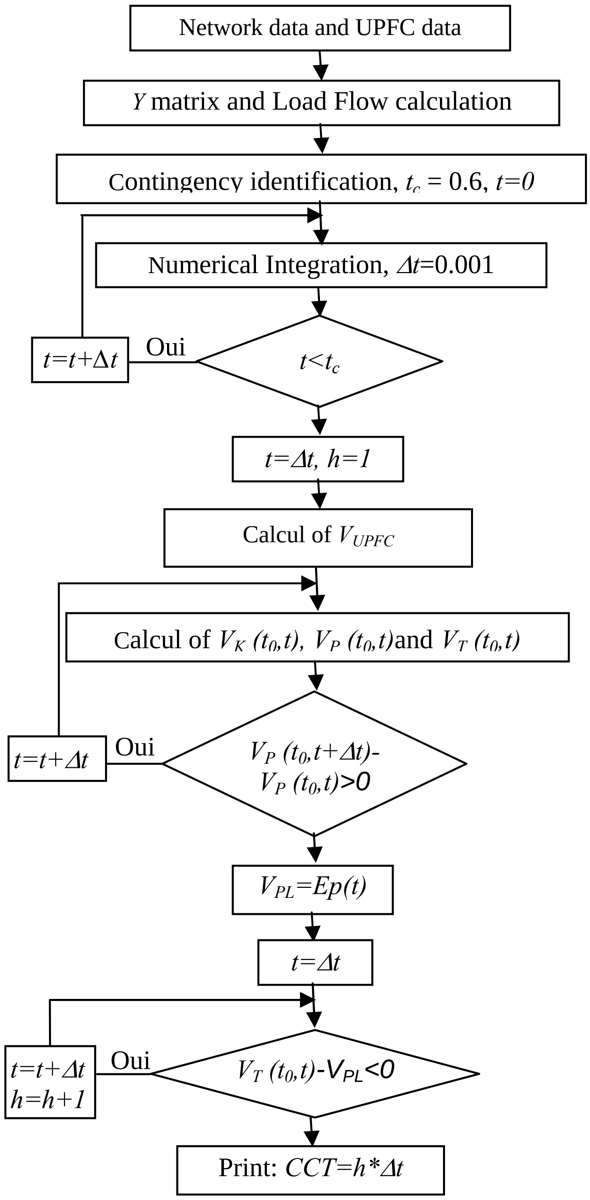

Fig.3. Flowchart of PEBS approach

5. Simulation results

The UPFC is connected between buses 2 and 10 and its parameters considered for all simulations are [5]:
U_T=0.03 pu, I_q=0.03 pu, φ_t=85° and X_{TRS}=0.06 pu
The contingencies considered in this study are the three phase short circuit followed by opening the faulted line. Results are presented in table 1.

TABLE 1. - Critical Clearing Time (s)

Faulted Line	Faulted Bus	CCT of System			
		without UPFC		with UPFC	
		PEBS	NI	PEBS	NI
1-2	1	0.506	0.51	0.547	0.56
5-9	5	0.402	0.41	0.435	0.47
7-8	8	0.525	0.54	0.539	0.55
8-9	9	0.547	0.56	0.549	0.58
4-7	4	0.510	0.52	0.525	0.55

Results in table 1 demonstrate the ability of UPFC to enhance power system transient stability. They demonstrate also that the proposed algorithm based on PEBS can evaluate the CCT but it gives conservative values. Nevertheless, they can be used for on-line dynamic security assessment because they are faster than numerical integration approach.

6. Conclusion

In this study, a new computationally fast tool is developed to evaluate the system transient stability Critical Clearing Time in a range of a hundred of milliseconds. The PEBS approach is used to achieve this goal. The used Transient Energy Function considers a detailed model of generators and containing an additional term which represent the UPFC effect. Results show the ability of the proposed algorithm to evaluate the first swing transient stability of power system with UPFC. A generalised software MATLAB tool is elaborated for both numerical integration and energy function methods. Simulations performed through the studied systems give promising results. For further work, we propose to use other approaches based on Energy Function to precisely evaluate the CCT and to use this tool for assessing system transient stability margins, such that proper emergency control mechanisms can be activated in order to maintain stability and ovoid large catastrophic outages.

7. References

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