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On line diagnosis of capacitor switching effect to prevent voltage collapse

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ABSTRACT

Emergency actions are performed to recover voltage after a disturbance. The optimal emergency actions are calculated immediately after disturbance based on the current state and applied when the calculations are completed. But because of the dynamic nature of the loads, the system state is changed in this interval, so the calculated actions may no longer be effective. This paper presents a method to fast distinguish the emergency action effect to recover voltage. This is based on the measurement of actual load powers and voltages in the instant the actions are applied and using the concept of attraction region. The diagnosis can be only performed by algebraic calculations, but a short dynamic simulation is sometimes required. The focus is on the capacitor switching as a common used emergency action, but the results can also be used for the other actions.

1. Introduction

Voltage collapse increasingly occurs in many power systems around the world [1]. The actions are intended to prevent voltage collapse can be divided into preventive and corrective ones [2,3]. The preventive actions are applied when the system is voltage stable, but the stability margins are small. While the aim of the corrective actions is to stabilize an unstable power system. Both actions are determined in energy management systems (EMS) to protect the power system against the probable disturbances and can be executed in either a pre-disturbance or post-disturbance mode [2]. But since all possible disturbances can not be foreseen at planning stage, in some cases the voltage collapse occurs [4]. In these situations, emergency actions such as changing terminal voltage setpoint of generators, switching capacitor banks, controlling transformer taps and finally load shedding are required. When a disturbance is identified, the emergency actions must be determined and applied as soon as possible because the faster the emergency actions are applied the less amounts are required [5].

Considerable researches have been carried out to determine corrective (emergency) actions aimed at preventing voltage collapse using minimum control effort [2–10]. The objective of many of proposed methods is only to restore the system solvability considering allowed operation limits [6–8]. These methods use the long-term equilibrium model of the system without considering the evolution of system voltages and analyzing the system ability to reach the new steady-state operating point. As the delay in applying the emergency actions decreases this ability, the calculated actions are probably useful only if executed before or immediately after disturbances. These methods must be completed considering the dynamic aspects of the voltage stability including the time evolution of voltages and the problem of the exit from attraction region. In Refs. [4,9,10] the optimal emergency actions have been obtained based on a system model-based method named model predictive control (MPC). In this method, the evolution of system voltages for different emergency actions is predicted using the system model. A cost function has been defined based on the deviation of each predicted voltage trajectory from a desired one. The optimal emergency actions are those that minimize the defined cost function. The calculations start immediately after disturbance based on the current state and the optimal emergency actions will be applied as soon as they are determined. These references use the system state only in the instant of disturbance, but the determination of the optimal emergency actions takes a considerable time that over which the system state changes. In these conditions, the voltage decrease can continue in spite of applying the calculated actions because the system state may exit from the attraction region of new steady-state operating point.

Very few methods have been proposed which consider the attraction region. In [11], a method to determine the critical switching time of capacitors considering the attraction region has been reported. The *Q*–*V* curves and dynamic load models are used to calculate the time in which the system state exits from the attraction region. The calculations are performed without considering any interaction between different loads.

The aim of this paper is not to determine the emergency actions but to analyse the effect of the determined actions using the concept of the attraction region. It is shown that the maximum allowable time to apply the emergency actions can be greater than that

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