Distributed Voltage Control in Electrical Power Systems

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1 Introduction

Hybrid nonlinear behavior of power systems often involves an intrinsic strong coupling between continuous dynamics and discrete events, particularly during voltage collapse phenomena when many discrete devices (either controllers like Load Tap Changing (LTC) transformers or thresholds influencing continuous dynamics like Over eXcitation Limiter (OXL)) switch on and off. Traditional block-oriented tools like Matlab/Simulink for modeling and simulation of power systems suffer from *causal modeling* meaning that blocks have a unidirectional data flow from inputs to outputs. This is the reason why some components cannot be simulated easily because there will be a loop which only contains algebraic equations. This is a well-known drawback of Matlab/ Simulink which is not always able to handle the algebraic loops. In order to overcome the above-mentioned drawback, A hybrid framework accounting for both continous as well as discrete dynamics of power systems, and based on acausal modeling, has been proposed. Simulation results show that the interaction between continuous dynamics of the power system and hybrid automata representing the discrete logical controllers, and also the nonlinear behavior of load dynamics, can easily be studied in the proposed framework [1]. On the other hand, the simulator is sufficiently fast to predict the effect of a future control action, faster than in real time.

According to the literature, many voltage collapse incidents have been caused by uncoordinated interactions of local controllers following a major disturbance in the power systems. LTC controls, as the most likely driving mechanism of voltage collapse in long-term, is of special interest. There has been relatively little attention paid to devising a truly model-based coordinated feedback control of LTCs. This study applies the distributed MPC theory, with on-line agent-wise optimization, to the coordinated voltage control problem. Simulation results show the potential for avoiding voltage collapse by messages exchange among neighboring local controllers under severe disturbances[2].

2 Distributed Model Predictive Control (D-MPC)

Distributed MPC relies on the partition of the power system into different regions as shown in Fig. 1. A set of buses located at a relatively short electrical distance from each other with relatively coherent voltage variations are considered as one particular region. The interaction among different regions arises from power flows P_{ij}, Q_{ij} of active and reactive through lines interconnecting neighboring regions. Each agent solves its own local MPC optimization problem using a reduced-order model of its own region, local measurements, local costs and local constraints. Moreover, after each update of the local MPC control action, each agent sends the selected optimal sequence of the local control actions to its neighboring agents. Assuming that agent i has at least an approximated model for predicting how control actions of neighbor j influence interaction variables $x_{ij}(t)$, this knowledge allows agent i to coordinate its action with what neighbors are likely to do.

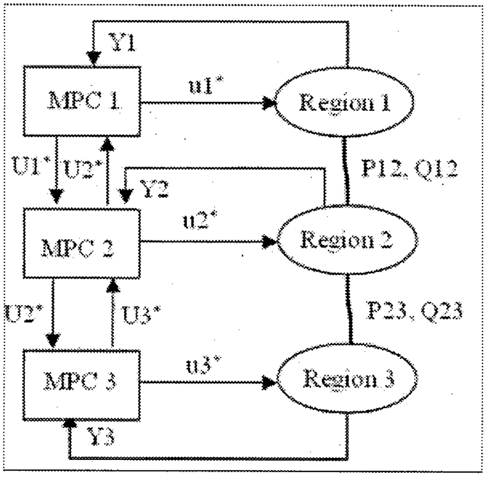

Figure 1: Distributed MPC applied to a 3-regoin power system

References

[1] M. Moradzadeh and R. Boel , "A Hybrid Framework for Coordinated Voltage Control of Power Systems," IPEC2010.

[2] M. Moradzadeh, L. Bhojwani, and R. Boel, "Coordinated Voltage Control via Distributed Model Predictive Control," CCDC2011.