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# Output Feedback Security Control for Discrete-Time Piecewise Homogeneous Semi-Markov Switching Power Systems with DoS Attacks

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## Abstract

For the discrete-time piecewise homogeneous semi-Markov switching power systems with denial-of-service (DoS) attacks, this paper proposes an output feedback safety control method. Firstly, two upper homogeneous Markov chains are introduced to adjust the residence time probability mass function and the transition probability of the embedded Markov chain, thereby constructing a more generalized piecewise homogeneous semi-Markov kernel. Secondly, to address the issue of difficulty in obtaining all state information in complex power system environments, a more effective output feedback safety control scheme is designed. Additionally, considering the influence of random DoS attacks and the piecewise homogeneous semi-Markov kernel, a Lyapunov function related to the system mode, residence time, and piecewise homogeneous parameters is constructed, and on this basis, verifiable numerical stability conditions for the system are derived. Through case analysis, the effectiveness and practicality of the control method are verified.

## Research Questions

1) **Security issues of power system under DoS attack:** This study explores how to ensure the stability and reliability of the power system when it is subjected to DoS attacks, especially in cases where information transmission is blocked.

2) **Control problem with missing state information:** Considering that some internal states in the power system cannot be directly observed, the issue of maintaining system stability when it is impossible to obtain complete state information.

## Methodologies

1) **Piecewise homogeneous semi-Markov switching model:** By dividing the system into multiple time periods, it takes account of the changes in system parameters, enhancing the flexibility and accuracy of the model, and introducing two upper-level Markov chains to describe the switching behavior.

2) **Output feedback security control:** For system states that cannot be directly observed, an output feedback control strategy was designed. The Lyapunov function was utilized to ensure the stability of the system under DoS attacks.

## Mathematical Formulas

Consider the following segmented homogeneous semi-Markov chain to describe the changes in different structural parameters.

$$s(k+1) = A_{\alpha(k)}s(k) + B_{\alpha(k)}u(k) \tag{1}$$

$$y(k) = C_{\alpha(k)}s(k) \tag{2}$$

The actual measured output $y_{act}(k)$ under DoS attacks is given as

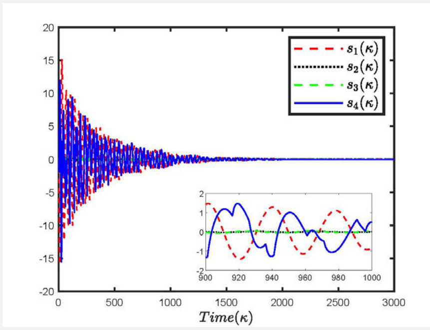
$$y_{act}(k) = \beta(k)y(k) + (1 - \beta(k))y(k-1) \tag{3}$$

The output feedback security control strategy is designed as

$$s'(k+1) = A_{rmc}s'(k) + B_{rmc}y_{act}(k) \tag{4}$$

$$u(k) = C_{rmc}s(k) \tag{5}$$

## Figure




Based on the calculated controller gain, the system state response as shown in the figure is obtained. The system was able to converge rapidly, verifying the effectiveness of the designed controller.

## Conclusion

This study explores the problem of output feedback safety control for power systems under random DoS attacks and segmented homogeneous semi-Markov switching parameters. By introducing two upper-level Markov chains, a more accurate model of the complex power system is established. Combined with the Lyapunov function depending on the system mode, dwell time and the upper-level Markov chain, a criterion for ensuring the stability of the closed-loop system is formulated. Finally, the effectiveness of the output feedback safety controller is verified through a power system model.