Volatility of Power Grids under Real-Time Pricing

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The paper proposes a framework for modeling and analysis of the dynamics of supply, demand, and clearing prices in power system with real-time retail pricing and information asymmetry. Real-time retail pricing is characterized by passing on the real-time wholesale electricity prices to the end consumers, and is shown to create a closed-loop feedback system between the physical layer and the market layer of the power system. In the absence of a carefully designed control law, such direct feedback between the two layers could increase volatility and lower the system's robustness to uncertainty in demand and generation. A new notion of generalized price-elasticity is introduced, and it is shown that price volatility can be characterized in terms of the system's maximal relative price elasticity, defined as the maximal ratio of the generalized price-elasticity of consumers to that of the producers. As this ratio increases, the system becomes more volatile, and eventually, unstable. As new demand response technologies and distributed storage increase the price-elasticity of demand, the architecture under examination is likely to lead to increased volatility and possibly instability. This highlights the need for assessing architecture systematically and in advance, in order to optimally strike the trade-offs between volatility, economic efficiency, and system reliability.

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