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On the nature of voltage impasse regions in power system dynamics studies

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Abstract— This paper presents a fundamental study of voltage collapses that occur on a post-fault trajectory of a stressed power system in seconds after large disturbances. The focus of the study are voltage collapses that are induced by certain load models. Using an n-machine-N-bus power system model, the paper explicitly shows that the voltage collapse is caused by the non-existence of a real, positive solution for a load voltage magnitude in different areas of a relative rotor angle space when the load is of non-linear type. These «areas without voltage solution» are denoted as Voltage Impasse Regions (VIR) and are mathematically characterized as trigonometric functions of (n-1) relative rotor angles. Once the post-fault trajectory enters a VIR, voltage magnitude solutions become complex or negative, the algebraic Jacobian becomes singular and the behaviour of a system becomes undefined. The case study has been carried out using a simple 3-machine-1-load system with static load models. In the study, VIR appeared and enlarged as the non-linear (constant power and constant current) load increased. Furthermore, the non-convergence of time domain solution occurred exactly at VIR, thereby confirming that the problem is of structural nature.

Index Terms— Load models, power system dynamics, stability assessment, voltage collapse, voltage impasse region

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