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Under-Frequency Load Shedding (UFLS) Schemes – A Survey

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Abstract
The Under-frequency Load Shedding (UFLS) scheme has been used by utility companies around the world to mitigate frequency drop caused by simultaneous or cascading tripping of transmission lines and/or generators in a power system. In the effort to devise an optimal load shedding scheme, it is imperative that investigations are done on the many factors that may affect the response of the scheme in the event of a system contingency. This paper starts by analysing the implementation of UFLS in various power utility companies in Asia, Europe, Australasia, South Africa, Middle East and the Americas. It is observed that UFLS in these continents differ in terms of total load shed, number of UFLS blocks, average block size and trip frequency deviation thresholds depending on their system size, system inertia and generation mix. This paper also looked at the usage of System Frequency Response (SFR) models in the computation of UFLS and system parameters. Analysis on the SFR model showed that the impact of voltage dependence of loads was not taken into consideration in the early implementation of the model albeit load characteristics have significant influence on the dynamic behaviour of power systems during low frequency oscillation and severe faults. SFR model incorporating frequency and voltage dependence load models was proposed later in literature and used in the design of an optimal UFLS scheme. Investigation was also conducted on UFLS operating philosophies in terms of load shedding trigger, power imbalance estimation and distribution of load shedding. UFLS operating philosophies based solely on frequency parameters is inadequate to determine the stability of a power system especially for an islanded power system following severe disturbances. The power system may be susceptible to voltage collapse as well, which will lead to total system blackout within shorter time duration as compared to a frequency collapse phenomenon. Hence, trigger condition considering voltage information and voltage stability criterions were introduced and implemented in UFLS schemes. Distribution of load shedding based on power flow tracing method catering for both frequency and voltage instabilities was also introduced and proven to give optimal system response.

Keywords: Under-frequency Load Shedding (UFLS), frequency drop, load shed, System Frequency Response (SFR) model, operating philosophies.

Introduction

Under-frequency Load shedding (UFLS) is a common demand reduction measure taken by most energy utilities to mitigate frequency drop whenever there is dangerous imbalance between loads and generation due to disturbances to the system such as loss of generation or major transmission lines. UFLS is performed to force the perturbed system to a new equilibrium state, balancing load and generation, to minimize the risk of a further uncontrolled system separation and loss of generation and to prevent continuous frequency drop which may lead to total frequency collapse and prolonged system outage [1].

UFLS has to be well-coordinated between interconnected power systems and also with other system defense schemes such as Under-Frequency Capacitor Shedding (UFCS), Under-Frequency Generator Isolation (UFGI), Special Protection Scheme (SPS), Under-Voltage Load Shedding (UVLS) and other automatic actions that will kick in to arrest system from collapsing during abnormal frequency, voltage and/or power flow conditions [2]. For power system that has industrial and commercial customers with local generation connected to it, UFLS can detect onset of disturbance, isolate power systems by opening system ties and trip non-essential industrial loads to match total loss of generation. However, tripping these tie lines having active parallel generation reduces the beneficial impacts of load shedding because the sources of generation supporting system inertia are eliminated.