Corrective Strategies during Power System Emergencies

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Introduction

Cascading outages in power systems can initiate a blackout, something that power system operators and planners actively seek to avoid. The sequence of events leading to a cascade might start with a single line being opened. Alleviation of line overloads is the suitable corrective control actions to avoid network collapse due to contingency.

Control strategies to limit the transmission line loading within the security limits are generator rescheduling and/or load shedding. However, all generators and load buses in the system need not take part in overload alleviation. The selection of generators and load buses for control actions is a crucial task for the system operators. A fast identification of the participating generators, loads and proper control actions are essential for secure and reliable operation of power system. The basic operation is shown in Figure 1.

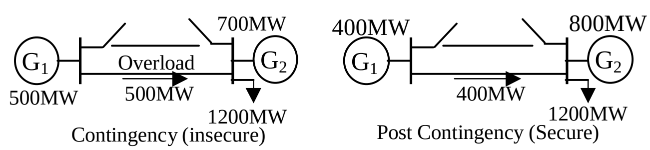

Figure 1: The basic Operation of a Power System

Corrective control Strategy

An operator executes a sequence of control actions to alleviate line overloads due to contingency of one or more lines:

1. Decrease the bus power injections at the sending end bus of the contingency line.
2. Maintain constant bus power injections at the receiving end bus of the contingency line by increasing the generation at this bus and/or at the feeder buses feeding.
3. Satisfy all the line constraints by curtailing the load at the receiving-end participating loads to which power is being fed from this bus.

The above process is applied to *participating generators*. The selection of participating generators is often achieved using graph theory. A directed acyclic graph (DAG) that divides the participating generators and load buses into two groups [generator decrease (GD) and generator increase (GI) group] according to the control actions. The corrective control strategy is an optimization problem, which is explained in the block diagram shown in Figure2.

Problem Formulation

Power Systems are highly nonlinear and poses several control challenges such as generation limits, voltage limits, line limits etc. Based on the above the control strategy is divided into two groups of optimization problem as follows.

GD group: The objective is to reduce the generation with respect to load such that the bus voltage constraints are within the limits. Determine an optimal set of generation P_{gi} *(i=1,2, . .NG)* that minimizes the total cost of generation F_t is given by

$$F_t = \sum_{i=1}^{NG} (a_i P_{gi}^2 + b_i P_{gi} + c_i)$$

GI Group: Increase the generation within the generator limits so as to meet the demand, if not possible, switch to load shedding. The objective function is:

$$f(x) = 0 \cong \sum_{ij \in all} (S_{ij} - S_{ij}^{max} * Sf)^2 = 0$$

The equality and inequality constraints are given below.
Equality constraints

$$g(x) = 0 \cong \begin{cases} P_{gi} - P_{di} - \sum_{j=1}^{n} V_i V_j Y_{ij} Cos(\theta_{ij} - \delta_i + \delta_j) = 0 \\ Q_{gi} - Q_{di} + \sum_{j=1}^{n} V_i V_j Y_{ij} Sin(\theta_{ij} - \delta_i + \delta_j) = 0 \end{cases}$$

The inequality constraints are

$$h(x) \le 0 \cong \begin{cases} P_i^{min} \le P_i \le P_i^{max} \\ Q_i^{min} \le Q_i \le Q_i^{max} \\ V_i^{min} \le V_i \le V_i^{max} \end{cases}$$

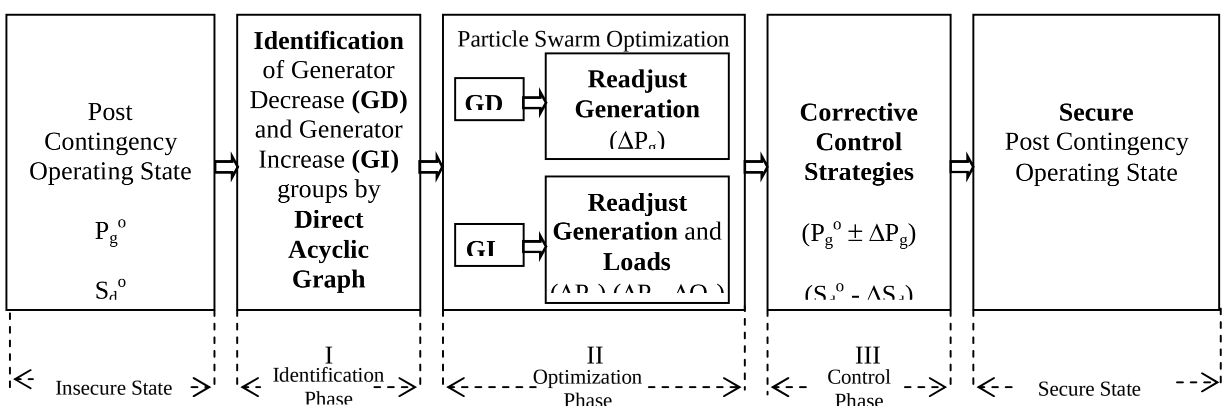

Figure 2. Block Diagram of Proposed Corrective Control Strategy

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