SC C6 Active distribution systems and distributed energy resources
PS1 Advanced distribution system design incorporating distributed energy resources

Energy storage application for improving transients performance of synchronous distributed generation

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Energy storages (ESs) play a key role in systems with distributed generation (DG), including renewable energy sources. One of ESs application benefits is the expansion of a range of admissible operating conditions for synchronous distributed generation based on gas piston engines, like biomass, wastes utilization, natural gas, etc.

The paper presents an analysis of DG disconnections by relay protection devices during short voltage dips and frequency deviations. The analysis shows that the excessive disconnections of DG units occur due to voltage dips when short-circuits in the adjacent grid are tripped by relay protection (RP) with high-value time settings. The effects of the excessive disconnection of DG units at industrial facilities include high volume of production wastage, accelerated equipment wear, significantly reduced production energy efficiency.

The method proposed in the paper provides expanding the range of admissible operating conditions of DG units by means ESs with independent control of active and reactive power. The implementation of control actions (CA) on ES enables to obtain an additional active and reactive power at the point of its interconnection and promptly shift the parameters of DG operating conditions out of the tripping area where they can be tripped by RP.

To assess the effectiveness of ESs use and to select the optimal CA values, a simulation modeling was conducted for a 6 kV grid part including an industrial facility $P_{load\Sigma}$ = 20 MW and a 4 gas piston units power plant of $P_{gen.Inst}$ = 10 MW. Composition of the load includes: synchronous motors - 10%, induction motors (IMs) - 62%, static (shunt) load - 28%.

Hybrid ES system in the test case consists of supercapacitors and battery energy storage. During the modelling ES output power and capacity required for successful CA implementation was defined. The capacity is defined as maximum required for 37,5 % load surge, 95 % load shedding and three-phase short-circuit on a power supply feeder in the island operation mode. The implementation of CA on ESs was made after the elimination of the short-circuit after 30 ms. The response time of modern

supercapacitor-based ESs is approximately ≈ 5 ms, however, in cases where the fault occurs outside the zone controlled by the automatic control system of the ESs, the limitations of a communication results in time delays.

It is shown that the realization of CA is ineffective, while the multiphase short-circuit fault is not eliminated. The effectiveness of fast forward CA (up to 30 ms) is revealed under the topology and state conditions when DG tripping is possible. The most efficient ES reactive power Q control principle is forcing principle up to 6 s. The effectiveness of the repeated CA using voltage triggering is described, taking into account the parameters and type of a transient process. It is stated in the paper that the best effect is achieved when $Q_{CA} / P_{gen} = 0.4–0.5$. The main influencing parameters are the relative power of $P_{gen} / P_{load\Sigma}$ and the short-circuit power level at the buses that generators are connected to.

The paper shows that the voltage dips and sags length during faults in external and internal power supply grids of industrial power areas is sufficiently longer than the fault duration itself, since after its elimination the voltage at the buses is reduced by the self-starting of electric motors. It is shown that the transient processes are more smooth if during the short-circuit fault period IMs slip does not reach its critical values that correspond to $t_{cr} \approx 0.07$ s.

The paper notices that preventing DG units' disconnection due to frequency deviations is most relevant for island operation of small inertia DG units. It is typical for generators based on gas piston engines. A variant of transient control is proposed. ES automatic control system operates in the tracking mode and at equal intervals T controls the frequency. If $f < f_{min}$, that is, a reduced DG power is detected, a CA is given to inject $+\Delta P_{ES}$, and, therefore, to increase the frequency; if $f > f_{max}$, then to consume $-\Delta P_{ES}$. The optimal values of T and ES power step sizes are determined based on the results of transient processes calculations.

It is pointed that ES CA to be implemented in proportion to the frequency derivative of $\Delta P_{ES} = -K_{df} \cdot (df/dt)_0$. The necessity of independent control ΔP_{ES} and ΔQ_{ES} in difficult topology and state conditions is discussed: load surges like starting a group of electric motors, 95 % load shedding, or short-circuit in the power grid. It is important that in all three transients caused by heavy disturbances, the proposed control prevents DG units from tripping with the same CAs, so there is no need to perform on-line selection of control algorithms using the parameters of the current state.

The results of the transients simulation for equivalent IMs indicate the successful start without DG tripping due to the ES support.

The main results of the work are the following.

1. A method for expanding the range of admissible operating states of DG units was developed. It is based on the independent ES ΔP_{ES} and ΔQ_{ES} output control preventing the unnecessary tripping of DG units during the significant deviations of the state parameters like frequency and voltage both in grid-connected and island modes;

2. Based on the simulation results, the effectiveness of ESs when short-circuits in the adjacent grid are tripped by relay protection (RP) with high-value time settings as well as during significant load surges and shedding is shown. The application of ESs ensures reliable power supply to consumers in various topology and state conditions;

3. Recommendations for carrying out calculations of electric states for the selection of optimal ES parameters (power and capacity) were developed.