“Generator Circuit-Breaker as a Means for a HILP Reduction Program”

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Background

The liberalization of electric power systems puts a strong pressure on the issues concerned with the reliability of power stations. In the vertically integrated system there was no explicit penalization in case of unexpected outages of generators. In a market scenario, where power stations are held by different generating companies, outages are more critical and may have significant economic consequences. Moreover, long unavailability periods (as in the case of severe failures of the main transformer) may affect the rate of return of investments related with power stations.
The application of generator circuit-breakers for the switching of generators at their terminal voltage offers many advantages when compared with the unit connection such as lower first costs, simplified operational procedures and better fault protection. Modern SF6 generator circuit-breakers make it possible to interrupt all types of fault currents within four cycles. This rapid clearance of fault currents helps to avoid expensive secondary damage of power station equipment and consequently long down times for repair. Although they have a low probability of occurrence such outages have a substantial effect on the availability of a generating unit. It is obvious that long unavailability periods as e.g. in the case of disruptive faults on step-up transformers may affect the rate of return of investments related with power stations. This is a classical so called HILP (High Impact – Low Probability) case.

Studies

Several studies were carried out for investigation of the impact of a generator circuit-breaker on the reliability of a power plant. The availability of large thermal power stations has been calculated by means of Monte Carlo simulation taking into account typical failure and repair rates of the power station equipment.

For example a simulation of the behavior of two Italian power stations was carried out with the help of the Monte Carlo method. The analysis provides important insights in the optimization of power station layouts, evaluating the possible introduction of generator circuit-breakers in existing schemes, as well as the possibility of applying different power station topologies. An economic evaluation of the different power station layouts is also provided, taking into account different scenarios in terms of energy selling price.

The simulations were carried out with a software tool called Power Plant Workbench™ by using the following data:
· Failure and repair time distribution of all components (the distributions can be exponential, Weibull, normal or log-normal).
· Mean value of the switching time (i.e. the time required for isolating a component) of all components.
· Probability of fail-to-open and fail-to-close of all circuit-breakers.
· Other quantities such as the probability of a failure of load shedding to unit auxiliaries load, the probability of a failure to transfer the supply of the unit auxiliaries, the probability of a Diesel generator start-up failure, etc..

The simulations were based on typical failure and repair rates of the power station equipment (taken from the literature and failure statistics of power plant operators and manufacturers) .

At the end of the year 1999 an unbalanced load condition due to a failure of one phase of a HV-breaker caused complete damage of one unit in the power plant of Turow in Poland. A group of professionals and academics was appointed to study the reasons and prepare remedies. Their reports have been presented during the conference "Accidents in the Power Plants" specially organized in Turow after the event. One of the main conclusions was: the accident could have been prevented if a generator circuit-breaker was used. The summary, conclusions and the recommendations are summarized in the paper "From the author's expertise of the accident in Turow", published by Prof. Jan Machovski of the University of Warsaw in *AUTOMATYKA ELEKTROENERGETYCZNA*, no. 1, 2001. One of the first recommendations resulting from the failure was "to proceed with installation of generator breakers in polish power plants during their rehabilitation.

Conclusion

The calculations carried out show that in comparison with the unit connection the average power throughput can be considerably increased when a layout with a generator circuit-breaker is used. The use of such a layout positively affects the power station availability especially in the following two ways:

- Firstly, the use of a generator circuit-breaker allows the unit auxiliary supplies to be drawn directly from the high-voltage transmission network at all times, i.e. also during the critical start-up and shut-down phases of the plant operation. Supply from this source is considerably more reliable than that from a local sub-transmission network and together with the avoidance of changeover switching operations required to transfer the supply of the unit auxiliaries from the station to the unit transformer (and vice versa) results in improved plant auxiliary equipment availability.
- Secondly, the rapid interruption of generator-fed short-circuit currents reduces the resulting fault damage and shortens repair times, thereby also contributing to an increased power station availability. Especially, generator circuit-breakers can prevent transformer tank ruptures and/or explosions and the associated severe consequences to the power station like damage to other equipment, fire, personnel jeopardy and serious environmental impact.

Finally, the reduction of power station unavailability brought about by the use of a layout with a generator circuit-breaker also results in a considerable economical benefit to the power station operator. The calculations show that the average down time of one unit can be reduced by about 50 hours per year when the layout with generator circuit-breaker is used. The resulting economical benefit to the operator of the power plant is considerable. Based on an energy price of $ 0.05 per kWh and on marginal costs (fuel costs and variable operation and maintenance costs) of $ 0.018 per kWh this corresponds to an annual surplus of receipts of $ 1,056,000.00 per 660 MW unit.

For more information about this subject see papers

Reliability and Economic Analysis of Different Power Station Layouts by
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From the author's expertise of the accident in Turow by Prof. Jan Machovski, University of Warsaw published in *AUTOMATYKA ELEKTROENERGETYCZNA*, no. 1, 2001.