Utility Practices in Phase Angle Regulator Operations

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The operating Areas surrounding Lake Erie are interconnected via synchronous AC tie lines. Several of these tie lines are equipped with phase shifting transformers that are intended for power flow control. This guideline provides principles and describes practices in using phase shifting transformers, commonly referred to as Phase Angle Regulators (PARs), to control line flows on the bulk power system. These practices are methods engaged in or approved by a significant portion of the electric utility industry, which, in the exercise of reasonable judgment accomplish the desired results consistent with good utility practices, reliability, and safety. These guidelines are intended to be applied to wide-area control and/or parallel flow control, but are considered reasonable for local control applications.

In a tightly interconnected grid, transmission line flows are affected by generation dispatch patterns, PAR adjustments, and transmission network topology in external systems as well as within an area. Scheduled power transfers between two parties will not only flow on mutual interfaces and/or agreed upon paths, but also normally appears as circulating power flow in other parts of the grid. The practices described herein provide for prudent and reliable operation of the interconnected power system during normal unconstrained conditions and when Operating Security Limits are exceeded during constrained and emergency conditions.

The practices described herein are recommended practices that should be followed to the extent possible. A practice described in this document is not intended to be limited to an optimum practice, method, or act to the exclusion of all others, but rather to delineate acceptable practices, methods, or acts generally accepted in the region. Local or other prevalent conditions may give good reason to deviate from these practices.

Control of PARs (Automatic and Manual)

Power flow through a PAR can be changed through automatic control or manual control of tap position. In either control mode, System operators must monitor not only the tap changes, but be cognizant of the effects of the power flow changes in other parts of the interconnected system to avoid creating or aggravating emergency situations. Following a contingency, PAR tap adjustments should be deferred to allow governor response, AGC, and other system control actions to correct the situation.

If tap positions are changed by automatic control, the control should be slow enough to allow for ordinary system changes such as generation shifts during schedule changes. System operators must be able to intervene and take control if, in the operator’s judgement, a situation jeopardizing system security is developing. Supervisory controls must have the capability to allow manual suspension of automatic control.

Automatic adjustments should be prohibited through automated control, to the extent possible, upon the occurrence of a contingency that affects the flows on the PARs. Some possible methods to automatically sense a contingency and then disable automatic control are to monitor one, or a combination of the following power system quantities:

- Step change in frequency, power flow, and/or voltage
- Rate of change of frequency, power flow, and/or voltage

Automatic control should not be restored until the system operator is aware that the system is returned to a normal and secure state following a contingency.
General Operating Practices

1. Transmission line flows should be controlled to maintain flows on facilities within Operating Security Limits at all times, to minimize parallel flows, and encourage appropriate use and reservation of transmission.

2. Phase angle regulators should be operated in a coordinated fashion to preserve the reliability of the system. PAR tap adjustments should not result in excessive power flow swings due to counter adjustments of taps on other PARs. (This may be achieved by appropriate use of deadbands on all PARs to dampen changes).

3. PAR control should not interfere with Control Areas’ tie line regulation, frequency control, or governor responses to disturbances.

4. PARs should be used to help in emergencies and to avoid creating emergencies.

5. Excessive or unnecessary tap changes should be avoided. Excessive tap changes will cause higher wear and tear on equipment and may lead to poor control of the power system. Less wear and tear will result in improved reliability because of fewer outages for maintenance or because of equipment failure.

6. Good communications among system operators in areas controlling PARs and areas impacted by PAR operations is necessary to minimize system constraints and preserve safe and reliable system operation.

A. Normal Conditions

PAR flow may normally be maintained close to a desired or scheduled flow, within an appropriate deadband and response time. PARs should be operated so as not to cause emergencies in other parts of the network. It is recognized that under unconstrained conditions a certain amount of parallel flow may be tolerated if it does not impair another system’s reliability.

When Operating Security Limits are not encountered in the interconnection and if operating to a target is not necessary, PARs may be left at the current tap. This tends to minimize the number of tap changes required and reduce maintenance and therefore increase the life and availability of the PAR equipment.

B. Normal Constrained Conditions

When constraints are imminent, PAR tap adjustments may be used in conjunction with other control actions to assist in mitigating constraints. Control Areas operating PARs and not experiencing any constraints will continue to operate the PARs as they would in the Normal Condition. PAR operators may make PAR tap adjustments, to the extent possible, to assist in alleviating an Operating Security Limit violation on a constrained facility while other local control actions are being taken by the CA experiencing the constraint. Control Areas at or near a constraint may request assistance from PAR Operators in making tap adjustments to alleviate constraints. The interconnection will be returned to a normal state within timeframes prescribed by industry standards. At such time PAR operations may be returned to the desired Normal Condition.
PARs should be operated to the extent necessary to protect equipment from overload (or the system from stability limits or low voltages) and not to cause emergencies in other parts of the network. Requests for PAR tap adjustments should NOT be made if the resultant flow results in or exacerbates constraints on another facility. If PAR flow adjustments cause conflicting constraints then moving PARs towards schedule has priority except in load shed emergencies. PARs operations in non-emergency constrained conditions to alleviate an internal or an external constraint should adjust power flow away from the Normal Condition only as much as is necessary to alleviate the constraint.

C. Emergency Conditions

When possible, adjustments to PARs should be made to alleviate constraints on any Control Area or system in an emergency. It is prudent to help a control area avoid firm load shedding, recover from an emergency, or avoid an imminent emergency. It is recognized that such actions will create additional parallel flows. This additional parallel flow is created intentionally to relieve security constraints.

During and following emergencies, automatic control on PARs should be:

- suspended upon the occurrence of a contingency or emergency condition.
- restored by the system operator once the system is returned to a secure state.

Real Time Data Acquisition and Monitoring

The Control Area with operational control over the PAR must have appropriate telemetering facilities to monitor operating quantities in real time. These quantities must include, but are not limited to, real and reactive power flows, target flow schedules, tap position and range, and bus voltages.

Real time operating data values must be made available to neighboring Control Areas and or Security Coordinators through an appropriate inter-area data exchange network. Presently this is the NERC ISN. Surrounding Control Areas and Security Coordinators whose systems are significantly affected by power flow changes on a PAR must obtain the appropriate data to monitor the PARs.

Power System Modeling

It is recognized that most commercial power system simulation programs allow for transformer impedance adjustments at different tap positions for a phase angle regulator. When doing power system studies and contingency analysis, tap positions should be adjusted to reflect regulation to the desired or scheduled flow on a PAR.

For analyzing pre contingency situations the impedance should represent the actual tap position at the desired or scheduled flow on a PAR. For analyzing post contingency situations, taps should be assumed to remain fixed, at their pre-contingency impedance, allowing for free flow through the transformer.