Abstract

The state of a given power system i.e. voltage magnitudes and angles at all the buses can be computed using the Newton-Raphson Load Flow(NRLF) method when active power and reactive power loads are specified at all the buses of the system. This computation can be carried out more efficiently(in terms of computer memory and time) using the Fast Decoupled Load Flow(FDLF) method for a large class of systems. These methods are the most widely used methods in power system studies.

NRLF and FDLF methods require modifications, if voltage magnitude is specified at some of the generator buses instead of the reactive power load. In such situations, generator reactive power outputs(manipulated by adjusting the field excitation) have to be adjusted to meet this specification. This necessitates the determination of the value of these additional control variables. There are some more similar adjustments that are required to be made in a practical load flow. Sometimes, the voltage at some load buses may be specified. They are to be maintained at the scheduled value using the taps on in-phase transformers(OLTC transformers). Similarly, it is possible in some situations that the active power flow in some lines are specified to be kept at a particular value. The device which facilitates such a control is the phase shifting transformer(PSTs) and the PST tap value is the additional control variable to be determined. The other operation of interest in interconnected power systems is the area interchange control(AIC). This requires that the sum of active power flow between two areas of the system is maintained at the specified value. The control variable value that enables this adjustment is the active generation in a particular generator bus in the area referred to as a swing bus. The load flow problem is referred to as a adjusted load flow problem in cases where in, some of these control variables must also be determined in addition to the state of the system.

It must be pointed out here that the control variables must be strictly kept

within their limits while bringing the controlled variables to their specified values. If a control variable tends to reach a value beyond its limits, then it is to be set at the limit and the corresponding controlled variable will not be at its scheduled value. Adjusted load flow problems generally involve many control variables of the same type or multiple control variables of different types. The challenge in finding adjusted load flow solutions stems from the fact that the relation between the controlling and controlled variables is not one to one; each controlling variable affects many of the controlled variables.

The existing approaches of adjusted load flow solutions generally consider only one type of these adjustments. There are only a very few attempts where more than one type of adjustment is considered. The two broad directions pursued for developing algorithms for adjusted solutions, by the earlier researchers are (1) Introducing additional equations in order to include control variable(between iterations) and (2) Adjusting the controlling variables between unadjusted load flow solution iterations based on the local sensitivity of the controlled variable with respect to a particular controlling variable. The schemes in use for finding adjusted load flow solutions have a flavour of trial and error type of algorithms. Their success in any situation is known to depend on specific details of implementation. Implementation details that guarantee success are not in the public domain. Many times they exhibit oscillatory convergence behaviour requiring very large number of iterations or fail to converge. It is also known that in some situations these algorithms could converge to anomalous solutions(solutions that are inconsistent with practical system behaviour). Such limitations of the existing approaches and also the need for developing better methods is well documented in the literature.

Some recent work has shown the promise of the formulation of the adjusted load flow problem in the complementarity framework considering a few of the adjustments. This thesis is intended to further explore this promising direction of investigation. In particular, in this thesis, we develop new algorithms in complementarity framework for the following situations and demonstrate their attractive features as compared with the existing approaches.

In this thesis, the following algorithms have been proposed, developed, tested and their performance compared with the existing algorithms. .

- Two algorithms for including OLTC adjustments, in the FDLF method as Mixed Complementarity Problem(MCP) and Non-linear Complementarity(NCP) formulations.
- In addition, the above algorithms are further extended to incorporate generator bus Q-limit adjustments simultaneously with the OLTC adjustments.
- Two new algorithms(two each in MCP and NCP formulations) are developed to handle generator Q-limits and OLTC adjustments individually as well as together in the NRLF formulation in rectangular coordinates.
- Four algorithms(two in MCP and two in NCP) to handle PST constraints in NRLF and FDLF methods.
- Four algorithms(two in MCP and two in NCP) to handle AIC constraints in NRLF and FDLF methods.
- In addition, the PST and AIC adjustment algorithms above are combined to simultaneously carry out PST and AIC adjustments in NRLF as well as FDLF methods.
- Four algorithms(two for NRLF and two for FDLF) to simultaneously incorporate all the four adjustments simultaneously using MCP and NCP formulations. These algorithms are also shown to be capable of incorporating simultaneously any subset of these four adjustments

The thesis focusses only on incorporating adjustments in the NRLF and FDLF methods as they are the most widely used schemes in the industry as well as the academia. It is also pointed out that the investigations here consider the adjustment problem in the traditional framework and hence, none of the power electronics based control equipment or the modern distributed generation sources are considered here.

Results of extensive computational experiments are presented and the attractive performance of the new algorithms as compared with the traditional ones are highlighted. All the new algorithms developed here are fundamentally different from the existing adjusted load flow approaches(not based on complementarity framework) in that they meet the specifications on the system variables and limits on the controlling variables automatically; without requiring either heuristic algorithmic choices or problem specific algorithm manipulation - a fairly common feature in all the existing approaches. This extremely desirable feature of the proposed algorithms is due to the fact that the proposed formulations for the adjusted load flow problems in complementarity framework, transform these problems to that of solving a fixed set of non-linear equations.

The results in the thesis provide strong evidence of the promise of the new methods for adoption into the widely used NRLF and FDLF programs so as to make solving the adjusted load flow problem as simple as solving the unadjusted load flow problem.