# Chapter 8

# Synopsis and Future Directions

## 8.1 Synopsis

An electrical power system operates in the normal operating condition during most of the operating time, but nevertheless prompt reactions of the operating personnel are required in the event of operating limits violation. Especially after removal of disturbances such violations may frequently persist. It is therefore useful to provide a tool to procure suggestions to the operator concerning setting up operating conditions that will enhance the economic and security aspect of the system. A tool of hybrid genetic algorithm and knowledge based state assessment and enhancement scheme has been developed and reported within the scope of this thesis. This innovative approach essentially uses a hybrid (numerical and knowledge-based) scheme of:

- decomposed genetic algorithm based dispatch modules of
  - **active power**, responsible for the removal of network branch apparent power flow limit violations and addressing the issues of economics, using generating units' real power output as control variables;
  - **reactive power** with transformer taps, generator terminal voltages and shunt capacitors and reactors considered as control variables, addressing the important aspects of:
    - keeping the voltage profile within an acceptable range;
    - minimizing the total real power losses in the transmission network;
    - avoiding excessive adjustments of control variables;
    - real time execution of the recommended control adjustments;
- modeling of operators' judgement through **reactive power controller pre-selection mechanism** to search for only the controllers electrically closest to the nodes experiencing the voltage limits violations, using the network topology information, thus reducing the operators' workload;
- algorithmic routines which evaluate the current power system situation relying on SCADA process data; and
- an expert system based superior control to procure the particular measures and optional execution of the suggested optimal settings of control devices (remote control of certain control devices presupposed) autonomously.

This scheme is used to solve operational problems related to branch overloading or out of limit voltage levels, telling the system operators the adjustments to be made to control devices in order to alleviate branch flow violation or voltage limit violation.

The developed functionality verified separately within the frame of this work is ready to be **integrated** into an existing comprehensive **restoration guidance system** which cares for re-supply of loads after disturbances, thus enhancing the capabilities of this restoration system by contributing to secure transition to normal operation. Especially during and after clearance of larger disturbances the voltage profile as well as the generation schedule may considerably differ from normality; the specific feature of genetic algorithms not to be caught in local optima is of special advantage in such cases.

By the use of an operator training simulator replicating the real power system and SCADA, the entire system was tested and verified under a high degree of operational realism for two different German real power systems replicated on the simulator in all operational detail. From the practical application on these two power systems for a multitude of diverse scenarios, the following conclusions can be drawn:

- the results show that the hybrid system is able to solve operational problems related to the voltage limits violation and branch overloads;
- the hybrid system is efficient by combining robustness of genetic algorithm and flexibility of expert system;
- the system is being able to mimic the operators' action by using controllers' pre-selection mechanism to select the most voltage sensitive control devices, thus amenable to practical application, and would be a particularly useful tool to the system operator for emergency system voltage control applications;
- additional modules and rules can easily be incorporated because of the modular structure employed in this work, thus enhancing its functionality;
- the human proceeding is reflected in a transparent manner with the use of superior control by an expert system;
- Furthermore, the optional closed loop automatic control of suggested control devices minimizes the operators' interventions, thus anticipating future operation of power systems.

## 8.2 Future Directions

In examining the accomplishments of the hybrid scheme developed within the scope of this work, it could be seen that some unanswered questions remain. Some interesting and important directions for future research can be grouped into:

**Enhancing the performance of the hybrid system**

Since the approach of genetic algorithm was used to develop the components of real and reactive power dispatch, improvements can be made in their implementation in the following ways:

- The genetic algorithm is time intensive and the computational time itself strongly depends on the hardware used. The implementation of the work reported here was done on antiquated Apollo workstation (25 MHz); a speed up by a factor of 10 to 20 would be achieved only by the use of modern computer hardware. Another considerable factor could be gained by parallel computing of the load flow calculations to be performed on the individuals (control variables combinations) of each generation. Thus, the tremendous processing time demand of couple of minutes for the generation evolutions would be reduced to few seconds.
- In the implementation of GA, binary encoding was used. Other encoding methods like Gray and real value encoding can equally be used and the results compared with the ones obtained in this work.

Incorporation of other control devices that influence the flows of real and reactive power as for examples quadrature booster (phase shifting transformers) settings, Static VAR Compensators (SVCs) and use of line maneuver as discussed in chapter 2 into both the real and reactive power dispatch modules would further enhance the functional capability of the hybrid system.

**Extending the functions of the hybrid system**

- A mechanism that will perform units commitment before actual economic load dispatch is carried out could be added so that only the most efficient generating units are optimally dispatched by the real power module.
- The use of GA to coordinate the operation of systems with hydro-thermal generation will be an interesting challenge because of the existence of many and highly varied constraints.
- In case that all functionality implemented in this work has been applied and the operating limits violation still persists, other measures like load shedding

could be contemplated by the operator. Under this circumstance, a mechanism to procure the appropriate amount and selection of loads to be shed could be additionally implemented.