Abstract

Hydro power plants in general and hydro turbine in particular like any other real systems, are nonlinear and have time-varying parameters to some exrent. The hydrodynamics of the tunnel, penstock and turbine are complex due to nonlinear relationship, which exists between the water velocity, turbine inlet pressure and developed power. The performance of hydro turbine is strongly influenced by the characteristics of water inertia, water compressibility and penstock-wall elasticity. The dynamic characteristics of a hydro turbine power depend heavily on changes in set point and load disturbances. Thus the hydro turbine exhibits highly nonlinear, non-stationary system whose characteristics vary significantly with the unpredictable load.

A key item of any hydro power plant is the governor. Hydro turbine governing system provides a means of controlling power and frequency. The speed governor normally actuates the gates / vanes that regulate the water input to the turbine.

The hydro plants being site specific may have different configurations of their layout, however the main motivation of dissertation is confined to a small hydropower schemes, which can be as high head or low head. Small hydro power schemes with high head and thus connected to reservoir with long length penstock experience severe control problems due to occurrence of transients. This is due to pressure wave rise on sudden change of gate position, which in turn is adjusted to meet the load demand. Similarly a low head hydro plant connected as single machine infinite bus system experiences a critical low stability margin. The studies for such systems is a useful starting point for designers to evaluate the dynamic performance under alternative / new controller concepts. Subsequently, advanced control techniques are required to realize the full potential of the plant over a wide range of operating conditions to capture full plant characteristics.

The mathematical models of various elements of hydro power plant like hydraulic structures / components and electrical systems can be integrated to represent the plant as a single entity. To obtain accurate representation of the integrated system, the plant model can be identified either in open-loop or closed-loop using its input-output data. This will facilitate the implementation of new / alternative control approach to the plant model for effective operation during disturbance.

Recent literature survey indicate that the artificial intelligence (AI) techniques may be applied for the approximation / reduction for stable / unstable / non-minimum-phase complex

systems. With AI techniques, the plant controller suitable for real time operation can be designed.

This thesis considers the main emphasis to develop the detailed and extensive modeling necessary to represent a real world hydro power plant. The investigations have been carried out to include the dynamics of each component / structures of plant in modeling. The methodology adopted is based on the identification techniques to obtain a corresponding model suitable for the controller design under consideration. For this purpose, plant parameters referred in the bibliography are employed.

Irrational transfer function of penstock-turbine is reduced to a lower (first, second, third and fourth-order) order function using H-infinity approximation method and compared with Padé approximant method. Identification of hydro turbine / hydro plant for these reduced order transfer function (TF) models in (i) open loop and (ii) closed loop are discussed using fuzzy systems.

The low head hydro plant connected as single machine infinite bus system (SMIB) in state space form with two-input two-output (TITO) is formulated. Optimal pole shift control technique is employed to determine the feedback gain matrix. These gain matrix determined at any operating point ensured a satisfactory time response for other operating points too. A neural-network non-linear auto-regressive with exogenous signal (NNARX) model in open-loop is presented for this system. The optimal NN structure is determined using optimal brain surgeon technique. Its dynamic response is compared with the NN model structures for identification as suggested in the some literatures.

Next the research work towards the development of NNARX model is considered for high head hydro plant that includes tunnel, surge tank, and penstock hydraulic dynamics. This model is developed for identification of nonlinear dynamic relationship between (i) gate position (GP) - turbine developed power (TP) and (ii) gate position (GP) - deviated power (DP), with random load disturbance. With the identified model, NN based predictive control (NPC) is presented. The Levenberg-Marquardt (LM) and Quasi-Newton (QN) iterative algorithms are applied in optimization of control performance index. The controlled response is made to track different reference signals.

Next fused NN and fuzzy systems approach (i.e. ANFIS) is presented for the turbine speed identification under water disturbances (variation in water time constant) and the comparative performance with NNARX model is also discussed.

Modeling and approximation of input-output response function of hydro power plant (in closed-loop) following the unbalance load disturbance on each phase of the synchronous generator is examined and the salient characteristics are explored. Takagi-Sugeno fuzzy model is applied to obtain approximated gate position and turbine-generator unit speed response.

The approach as discussed above may be considered for model identification for real existing hydro power plants using its input-output data only. The model thus developed may be used both in the development and operational stages during the lifetime of the power plant. Design of control system can be facilitated once the model has been validated, against the real system data; a physical interpretation of the model parameters can sometimes be made.