Building the Dynamic Model of TRANSCO’s Power Transmission System

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Introduction
TRANSCO, the Abu Dhabi Transmission & Despatch Company, and Siemens PTI built a dynamic model for ADWEA (Abu Dhabi Water & Electricity Authority) power system. The network of TRANSCO consists of the voltage levels 400kV, 220kV and 132kV. Eight major power plants are connected to TRANSCO's power system and are located at Al Taweelah, Al Shuweihat, Sas El Nakheel and Al Fujairah. The PSS®E dynamic models were built for these power plants. Field tests at selected generating units were conducted in order to complete the data set and verify the existing parameters and data. Furthermore, dynamic load models for load representation of medium voltage feeder and large industrial sites had to be developed. The entire dynamic network model was validated by three selected incidents. The task was to gain a dynamic network model with good representation of the single generating unit performance and overall congruence at electro-dynamic events for the entire transmission network of ADWEA.

Methodology

General procedure
The general procedure and approach for executing this consulting project was:

1. Data collection at all power plants and major industrial loads
2. Creating a data collection book
3. Developing the dynamic model in PSS®E based on the data collection and data book
4. Defining the field test procedure
5. Selecting generating units for field testing
6. Field testing of the selected units
7. Model validation and parameter optimization of the selected units with the field test measurement with simulations in PSS®NETOMAC and PSS®E
8. Developing a load model
9. Combining all dynamic models in PSS®E
10. Entire dynamic model validation with records of random incidents
11. Finalizing the dynamic model and documented in a functional description

The project was accompanied by several training sessions including theory of power system dynamics and stability, simulation with PSS®E, usage of GMB (the graphical model builder) and model validation.

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Field Testing

The objective of the field tests was to measure the performance of the generating units in order to build and validate the dynamic PSS®E models of the units. The governor controllers including the turbine and...
the automatic voltage regulators (AVR) with the power system stabilizer (PSS) and excitation system were field tested in order to gain the model parameters. The performances of the dynamic PSS®E models were validated with the field tests.

For the selected generators, where appropriate data are missing or the verification by dynamic simulation of the collected generator data result in an unacceptable unit performance, field tests were carried out. Depending on the kind of discrepancy of the models, the considered field tests are:

- Step responses at automatic voltage regulator (AVR), e.g.:
  - Step response test (1..5 %) at no-load
  - Step response test (1..5 %) at load without power system stabilizer (PSS)
  - Step response test (1..5 %) at load with power system stabilizer (PSS)
- Step responses at governor, e.g.:
  - Step response test (0.1..2 %) at no-load
  - Step response test (1..5 %) at load mode
  - Repeat tests at different loads (base load, partial load)

The field tests were carried out by experienced commissioning engineers in close cooperation with TRANSCO’s system operators and responsible staff of the considered power plants. Due to various technologies and manufacturers of controllers at the generating units, several specialists for AVR and governors were engaged in field testing. Additionally, difficult contractual situations at the power plants led to the main challenges in the project to coordinate, instruct and guide the different stakeholder and specialists.

Model Validation

The records of the field tests were preprocessed and adapted for use in the simulation and comparison programs. In order to complete, build and validate the dynamic models, the following steps were applied:

1. The model parameters were identified and gained from the field tests using PSS®NETOMAC
2. The dynamic models where built in PSS®E
3. The dynamic models in PSS®E were optimized and validated with these field test measurements

With PSS®NETOMAC a first assessment, parameter identification and optimization were done unit-by-unit at a simplified single-machine infinite bus system. The starting parameters and models for the concerned units were selected based on the data book. The results of the parameter identification were transferred to PSS®E and validated with the field test records again.

Load Model

It is reported that the TRANSCO system has a slow voltage recovery problem due to the nature of the load in Abu Dhabi. One part of the load is motor load and the other part is static load. The motor load is categorized as follows:

- Motor load model for window type air condition (induction motor)
- Motor load model for HVAC water chillers (induction motor)
- Motor load model for cooling plant
- Dynamic load model for large industrial load

In order to assign the medium voltage load to a certain load representation, the areas of Abu Dhabi were clustered into three load cases. Each load case contained an estimated amount of commercial loads, small industrial loads and residential loads. Based on this definition, the static and dynamic load representation was calculated and included into the dynamic model of ADWEA. The validation was conducted by means of dynamic model validation by incidents of TRANSCO’s network. The load representations at high voltage level (mainly 220 kV) are large industrial sites and are assigned according
to details based on information gained in the data collection and type of production process, e.g. steelworks, aluminum smelter, chemical and process industry.

Entire Dynamic Model Validation

After field testing and model validation unit by unit, the developed dynamic models of the different generating units were combined in the entire network. The dynamic load models were added to the setup as well. The entire dynamic model was validated by measurements recorded during three selected incidents at ADWEA’s network. The performance of the dynamic network model was compared with available voltage and frequency records of high voltage substations. Furthermore, the several unit performances were verified with records of the power plant operating system. Generally the developed dynamic model matches with the recorded incidents.

Training

In parallel to the project execution four training sessions were conducted by Siemens PTI. The topics of the training sessions were:

1. Theory of Power System Dynamics and Stability
2. PSS®E - Introduction to Dynamic Analysis
3. Dynamic Modeling using the Graphical Model Builder (GMB)
4. Power System Dynamic Simulation with PSS®E and Model Validation

The training sessions imparted knowledge about the utilization of the dynamic models, understanding their performance and hands-on experience with the software products PSS®E and GMB as well as their own network including the dynamic model of TRANSCO developed during this project.

Results and Conclusion

A dynamic network model with very good representation of the single generating unit performance and overall congruence at electro-dynamic events was gained for an entire transmission network. The described procedure was successfully applied and the dynamic model of ADWEA was optimized, improved and validated. More clarification and settlement on the field test up-front including all stakeholders are essential to speed up the field test campaign. Finally, the project of building the dynamic model of ADWEA was successfully managed and the transmission system operator gained a very accurate and detailed simulation setup to simulate electro-dynamic events with PSS®E and GMB².