Voltage Depending Load Models. Validation by Voltage Step Tests

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Abstract— **This paper presents applications of the Exponential Static Load model used to represent voltage depending loads. This model has been used to represent loads of different types: Industrial, Residential and of Petroleum Extraction Fields.**

These loads belong to "Sistema Interconectado Patagónico" (SIP), a small power system of 1200 MW of peak load situated in the South of Argentina.

Models of several load types have been validated by tests.

Tests were made by applying steps to the feeding load voltage.

Load voltage sensitivity coefficients were obtained for the different load types tested.

Load models validated by tests were used for SIP modal analyses.

Index Terms-- **Load – Load Model - Power system dynamic stability – Simulation - Testing.**

I. INTRODUCTION

SEVERAL tests were made at medium voltage feedings of different loads. These tests were made to validate the modeling of different loads used for representation of voltage sensitive loads. Tested and modeled loads belong to SIP, a small power system of 1200 MW of peak load, situated in the south of Argentinean continental territory.

Different load types were tested: Industrial, Residential, of Petroleum Extraction Fields and several combinations of them.

Tests were carried out applying tap changes to the voltage feeding transformers. Test records were used to validate load model simulating load behavior with Simulink-MatLab.

Load models validated by tests were used to carry out small signal analyses to obtain SIP modal behavior as part of studies of power system dynamic stability carried out over the power system.

II. STATIC LOAD MODEL

A general form, named Polynomial Load Model, is normally used to represent Active (P) and Reactive (Q) powers of voltage dependent static loads, **[1]-[4]**.

Equations for this load representation are:

$$P = P_0 \left(p_1 \left(\frac{U}{U_0} \right)^{n_{P1}} + p_2 \left(\frac{U}{U_0} \right)^{n_{P2}} + p_3 \left(\frac{U}{U_0} \right)^{n_{P3}} \right) \qquad \textbf{(1)}$$

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$$Q = Q_0 \left(q_1 \left(\frac{U}{U_0} \right)^{n_{Q1}} + q_2 \left(\frac{U}{U_0} \right)^{n_{Q2}} + q_3 \left(\frac{U}{U_0} \right)^{n_{Q3}} \right) \qquad \textbf{(2)}$$

Where:

- P_0/Q_0: Nominal Active/Reactive power at nominal voltage U_0.
- p_1/q_1, p_2/q_2 and p_3/q_3: Distribution coefficients for Active/Reactive power, with $(p_1/q_1)+(p_2/q_2)+(p_3/q_3) = 1$
- n_{P1}/n_{Q1}, n_{P2}/n_{Q2} and n_{P3}/n_{Q3}: exponents for Active/Reactive power, where $n_{P1}/n_{P2}/n_{P3}/$ and $n_{Q1}/n_{Q2}/n_{Q3}$ are real numbers.

Usually, exponents for **(1)**-**(2)** are set to:

- $n_{P1}/n_{Q1} = 0$ to represent constant power loads.
- $n_{P2}/n_{Q2} = 1$ to represent constant current loads.
- $n_{P3}/n_{Q3} = 2$ to represent constant impedance loads.

For small voltage variations, Polynomial Load Model, **(1)**-**(2)**, could be replaced by Exponential Load Model described by the following equations:

$$P = P_0 \left(\frac{U}{U_0} \right)^{n_P} \qquad \textbf{(3)}$$

$$Q = Q_0 \left(\frac{U}{U_0} \right)^{n_Q} \qquad \textbf{(4)}$$

Where:

- P_0/Q_0: Nominal Active/Reactive power at nominal voltage U_0.
- n_P/n_Q: Active/Reactive power exponents, where n_P/n_Q are real numbers.

III. TESTS AND SIMULATIONS

A. Tests

Tests were carried out at several load feedings in the SIP over different load types: Industrial, Residential, of Petroleum Extraction Fields and several combinations of them.

Tests were conducted by applying steps to feeding load voltage. Voltage steps were generated by means of transformer tap changes.

For feeding points with two parallel transformers, one-tap changes for each transformer were applied sequentially.

Records of Active power (P), Reactive power (Q), Frequency Deviation (dF) and Feeding Voltage (U) were taken during tests.

B. Simulations

Test records were used to simulate load behavior with Simulink-MatLab, using the model shown in **Fig. 1**, where gray blocks are test records. The model used for simulations has load representation given by **(3)**-**(4)**. P/Q were simulated with the blocks "P/Q Model" respectively. Outputs P_s/Q_s are the simulated Active/Reactive power respectively.