Power System Modeling for Control Purposes

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*Jerome Cordjotse*

# Introduction

Microgrids, small-scale power generation, and storage technologies are examples of distributed power systems that are often used to supplement or improve traditional electric power systems. These systems are not the same as the large-scale, centralized power systems found in traditional power plants. Distributed power systems are situated near the load they service and are modular and flexible, in contrast to traditional centralized power plants. These systems can also function independently or be connected to the grid.

The N-bus system is studied and used to determine the power input's operating points inside the power system's dynamic model. Each bus is characterized by voltage, phase angle, and power injections. N-Bus modeling reflects power network topology, aiding in power flow, voltage regulation, and stability analysis, optimizing performance[]. The Y-bus matrix, derived from system parameters, models impedance and admittance between buses, vital for load flow and fault analysis[].

Power generation is model using a Differential-Algebraic Equations which combines the admittance matrix in the ohm’s law and the generator dynamic equation known as Swing Equation” .

# Modeling

## Simple N-Bus System

The two-bus system in figure 1 demonstrates how model the power system network of two buses with line impedance and impedance to ground.

A diagram of a number

Description automatically generated

Figure 1: Two-Bus System

The Admittance matrix can be derived in form:

Where is admittance of a line from to , with , signifying ground. The Ohm’s law equation becomes:

|  |  |
| --- | --- |
|  | (1) |

Where is the injected current into bus and is voltage at bus .

## Power Flow

To determine power flow from figure 2, the equation (2) is used.

A diagram of a rectangular object with numbers and letters

Description automatically generated

Figure 2: N-Bus System with power injection.

The power equation, where

|  |  |  |
| --- | --- | --- |
|  |  | (2) |

## Generator Model

Adding Generator , to figure 1 give a schematic in figure 3. No power is injected in bus 2, while the line impedance , from bus 1 to ground is infinite .

A diagram of a number

Description automatically generated

Figure 3: Two-Bus System with Generator at Bus 1

The voltage at bus one is known since this is the bus with the generation. The unknowns become , and , where

|  |  |
| --- | --- |
|  | (3) |

The Generator can be model with dynamics with its inertia from figure 4. This represents a swing equation (4).

A diagram of a circuit

Description automatically generated

Figure 4: Generator as an Inertia Dynamic System

|  |  |
| --- | --- |
|  | (4) |

Where . , are solved from the equation (3).

## Nine-bus System

The Nine-Bus System is a benchmark test case used in analysis to model a three-phase power system network made up of nine buses, or nodes, generators, loads, transformers, and transmission lines is modeled.

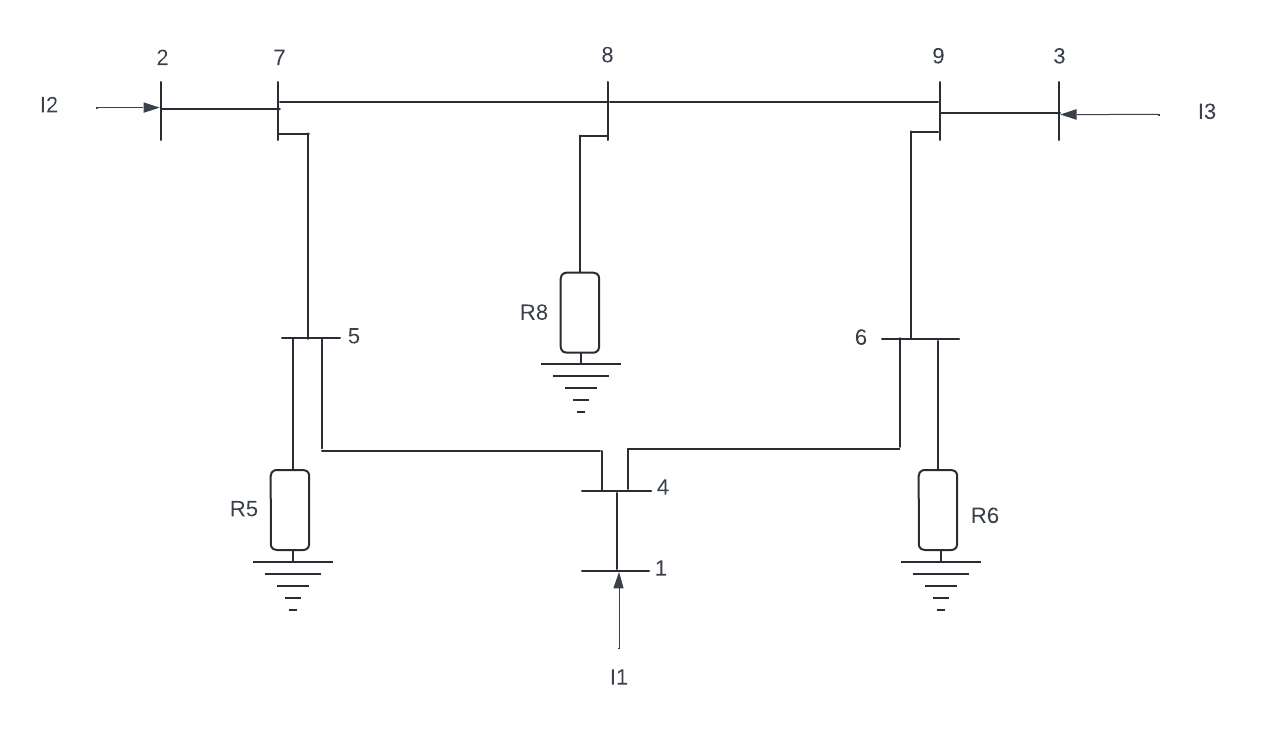


Figure 5: Nine-Bus Power System

The nine-bus system’s Ybus was generated in ma was model into practice generating large equations. The final goal was to generate the Differenial-Algebraic model of the nine-bus system for further test.

## Final Model

To generate the final model, the swing equation was expanded upon. The equation (4) in power networks that have many synchronous machines running simultaneously must account for the changing angular velocity relative to the other system. The relative positions of the rotor axis and the resulting magnetic field axis are fixed under typical operating conditions. The rotor angle is the angle created by the rotor axis’ relative motion in a synchronous machine. This motion reacts to disturbances in the synchronously rotating air gap and is initiated by the machine's acceleration or deceleration. This motion is quantified by the non-linear second-order differential equation known as the swing equation. The power transfer that results from rotor swing, either acceleration or deceleration, between the mechanical rotor and the electrical grid is known as inertial response.

The final Differential Algebraic Equation model combining (3) and (4):

|  |  |
| --- | --- |
|  | (4) |

# Simulation

## Ybus Generator

The control method proposed for this paper is to split the control into a cascaded controller for improved state response a robustness to parametrization. The outer loop controls the angular position which uses the Feedback Linearization technique for generating a control law for position with input torque and the inner loop for current tracking as shown in Figure.

## Steady State Solver

## Simulink ODE

Defining the nonlinear system in the form, , helps to implement the input-output linearization technique. The form is below:

|  |  |  |
| --- | --- | --- |
|  |  | (5) |

# Results

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