

## Purpose

This document is meant to explain PST additions and alterations created to accommodate AGC. Code examples are taken from the AGC example file `d2a_AGC.m` which is a modified version of `d2a_dce.m`.

## Area Definitions

To enable area calculations, each bus in the `bus` array must be assigned to an area in the `area_def` array. An example `area_def` array is shown below.

```
%% area_def data format  
% should contain same number of rows as bus array (i.e. all bus areas defined)  
% col 1 bus number  
% col 2 area number  
area_def = [ ...  
            1  1;  
            2  1;  
            3  1;  
            4  1;  
           10  1;  
           11  2;  
           12  2;  
           13  2;  
           14  2;  
           20  1;  
          101  1;  
          110  2;  
          120  2];
```

It should be noted that rows may not have to be in the same order as the bus array (untested). The `area_def` array is automatically placed into the global `g` structure.

```
>> g.area  
ans =  
    area_def: [13x2 double]  
    n_area: 2  
    area: [1x2 struct]
```

Each area currently contains values that may be relevant to AGC calculations. The `calcAreaVals` function is used to calculate and store such values. An example of what is stored in the `g.area.area(x)` structure is shown below.

```
>> g.area.area(2)  
ans =  
    number: 2
```

```
    areaBuses: [6x1 double]
      macBus: [2x1 double]
    macBusNdx: [3 4]
      loadBus: [4x1 double]
    loadBusNdx: [8 9 12 13]
      genBus: [2x1 double]
    genBusNdx: [6 7]
      totH: [1x4063 double]
      aveF: [1x4063 double]
      totGen: [1x4063 double]
    totLoad: []
      icA: [1x4063 double]
      icS: []
    exportLineNdx: [11 12]
    importLineNdx: []
      n_export: 2
      n_import: []
```

It should be noted that `icS` represents a placeholder for a scheduled interchange value and the `totLoad` is a field for collected total load. The collection of actual running load values may prove more complicated as the bus array does not seem to be updated every step, only a reduced `Y` matrix used in the `nc_load` function called from `i_simu`.

## Line Monitoring

Power flow on a line must be calculated each step as AGC requires actual area interchange for the ACE calculation. The previously existing `line_pq` function performed this task, but was not fully implemented into the simulation to allow calculation during execution. This minor oversight has been resolved and the `lmon_con` array is still used to define monitored lines as in previous version of PST.

```
%% Line Monitoring  
% Each value corresponds to an array index in the line array.  
% Complex current and power flow on the line will be calculated and logged during simulation  
  
%lmon_con = [5, 6, 13]; % lines between bus 3 and 101, and line between 13 and 120  
  
lmon_con = [3,10]; % lines to loads
```

Line monitoring data is collected in the `g.lmon` field of the global variable.

```
>> g.lmon  
ans =  
    lmon_con: [3 10]  
    n_lmon: 2  
    busFromTo: [2x2 double]  
    line: [1x2 struct]
```

Each `g.lmon.line` entry contains the following fields and logged data:

```
>> g.lmon.line(2)  
ans =  
    busArrayNdx: 10  
    FromBus: 13  
    ToBus: 14  
    iFrom: [1x4063 double]  
    iTo: [1x4063 double]  
    sFrom: [1x4063 double]  
    sTo: [1x4063 double]
```

### Weighted Average Frequency

An average weighted frequency is calculated for the total system and for each area if there are areas detected. The calculation involves a sum of system inertias that may change with generator trips. The current algorithm does not account for tripped generators, but was designed to incorporate this feature in the future.

In a system with  $N$  generators,  $M$  areas, and  $N_M$  generators in area  $M$ , the `calcAveF` function performs the following calculations for each area  $M$ :

$$H_{tot_M} = \sum_i^{N_M} MV A_{base_i} H_i$$

$$F_{ave_M} = \left( \sum_i^{N_M} Mach_{speed_i} MV A_{base_i} H_i \right) \frac{1}{H_{tot_M}}$$

Then system total values are calculated as

$$H_{tot} = \sum_i^M H_{tot_M}$$

$$F_{ave} = \left( \sum_i^M F_{ave_M} \right) \frac{1}{M}$$

If  $M == 0$ , `calcAveF` performs

$$H_{tot} = \sum_i^N MV A_{base_i} H_i$$

$$F_{ave} = \left( \sum_i^N (Mach_{speed_i} MV A_{base_i} H_i) \right) \frac{1}{H_{tot}}$$

## Automatic Generation Control

Under development...

The following AGC settings are rather fast and meant only to show and test the functionality of the AGC model.

```
%% AGC definition
%{
Experimental model definition akin to Trudnowski experimental code.
Each agc(x) has following fields:
    area          - Area number / controlled area
    startTime     - Time of first AGC signal to send
    actionTime    - Interval of time between all following AGC signals
    gain          - Gain of output ACE signal
    Btype         - Fixed frequency bias type (abs, percent of max capacity...)
                   0 - absolute - Input B value is set as Frequency bias (positive MW/0.1Hz)
                   1 - percent of max area capacity
    B             - Fixed frequency bias Value
    kBv           - Variable frequency bias gain used to gain B as B(1+kBv*abs(delta_w))
    condAce       - Conditional ACE flag
                   0 - Conditional ACE not considered
                   1 - TODO: ACE only sent if sign matches delta_w (i.e. in area event)

    (PI Filter Values)
    Kp            - Proportional gain
    a             - ratio between integral and proportional gain (placement of zero)

    ctrlGen_con - Controlled generator information (see format note below)
%}

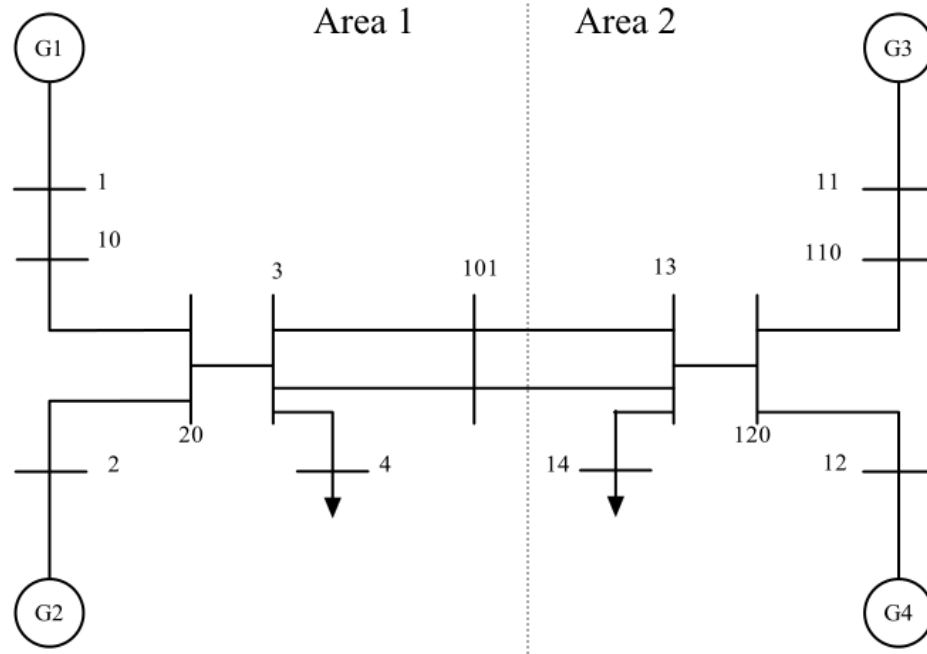
agc(1).area = 1;
agc(1).startTime = 25;
agc(1).actionTime = 15;
agc(1).gain = 2; % gain of output signal
agc(1).Kiace = 3; % gain of window integration average...
agc(1).Btype = 1; % per max area capacity
agc(1).B = 1;
agc(1).kBv = 0; % no variable bias
agc(1).condAce = 0; % no conditional ACE
agc(1).Kp = 0.04;
agc(1).a = 0.001;
agc(1).ctrlGen_con = [ ...
    % ctrlGen_con Format:
    %col 1 gen bus
    %col 2 participation Factor
    %col 3 low pass filter time constant [seconds]
    1, 0.75, 15;
    2, 0.25, 2;
];
```

```
agc(2)=agc(1); % duplicate most settings from AGC 1 to AGC 2

agc(2).area = 2;
agc(2).ctrlGen_con = [...
    % ctrlGen_con Format:
    %col 1 gen bus
    %col 2 participation Factor
    %col 3 low pass filter time constant [seconds]
    11, 0.25, 10;
    12, 0.75, 5;
    1;
```

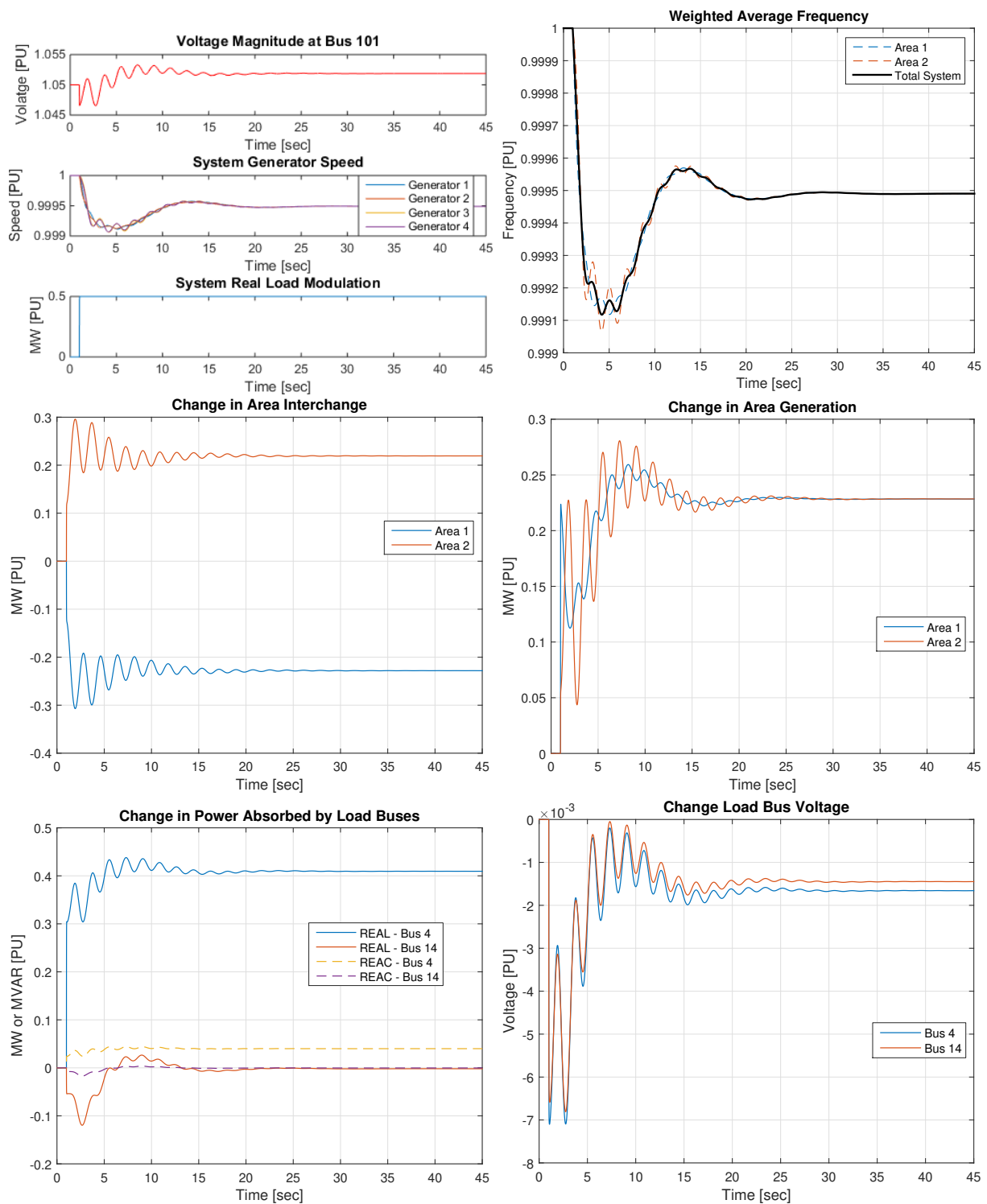
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## General Example Scenario Details



- Kundur 4 machine system packaged with PST
- Constant Z load model
- All machines, exciters, and gov's identical
- PSS on gen 1 and 3
- SVC on bus 101
- Event: +50 MW (0.5 PU) step of load on bus 4 at  $t=1$

## Initial simulation results (No AGC)





## Initial simulation results (with AGC)

