Purpose

This document is meant to explain PST additions and alterations created to accommodate AGC.

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, however the `lmon_con` array is still used to define monitored lines.

```
%% 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:

```
>> 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:

$$H_{tot_M} = \sum_{i}^{N_M} MVA_{base_i} H_i$$

$$F_{ave_M} = \left(\sum_{i}^{N_M} Mach_{speed_i} MVA_{base_i} H_i \right) / H_{tot_M}$$

Then system total values are calculated as

$$H_{tot} = \sum_{i}^{M} H_{tot_M}$$

$$F_{ave} = \left(\sum_{i}^{M} F_{ave_M} \right) / M$$

If $M = 0$, `calcAveF` performs

$$H_{tot} = \sum_{i}^{N} MVA_{base_i} H_i$$

$$F_{ave} = \left(\sum_{i}^{N} (Mach_{speed_i} MVA_{base_i} H_i) \right) / H_{tot}$$

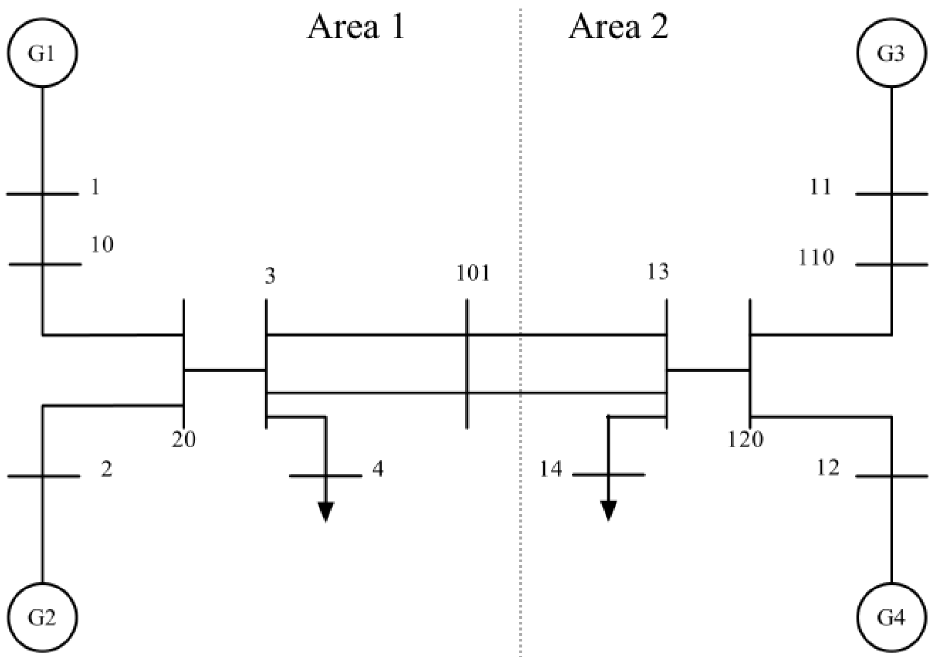
Automatic Generation Control

Under development...

```
%% 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
              1 - percent of max area capacity
    B           - Fixed frequency bias Value
    kBv         - Varaible 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

```

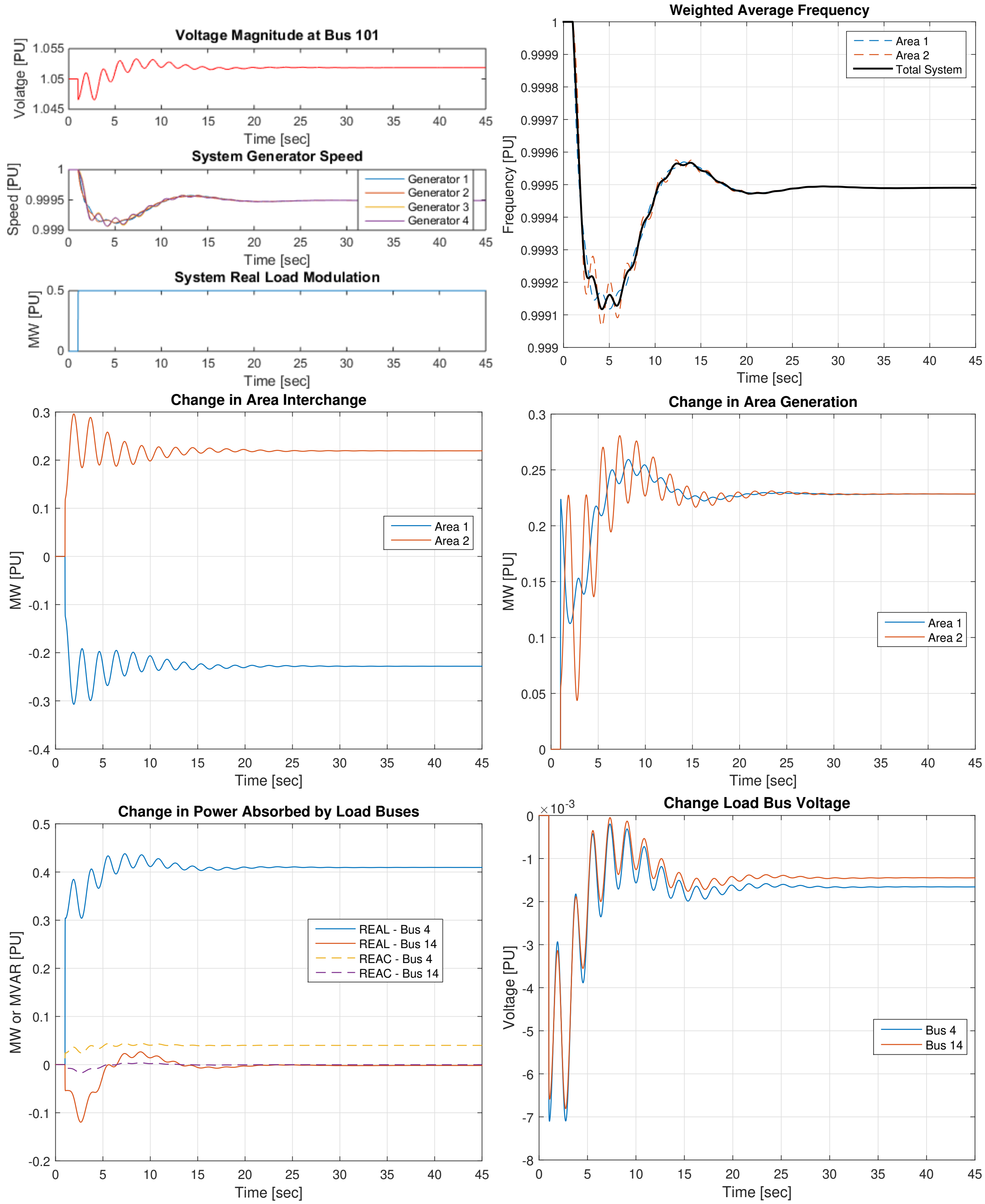
```
agc(2).area = 2;
agc(2).ctrlGen_con = [...
%    col 1 gen bus
%    col 2 participation Factor
    %col 3 low pass filter time constant [seconds]
    11, 0.25, 10;
    12, 0.75, 5;
    ];
```

General Example Scenario Details



- Kundur 4 machine system packaged with PST
- Constant Z load model
- All machines, exciters, and govs 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)