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Model Order Reduction of an ISLANDED MICROGRID Using Single Perturbation, Direct Truncation and Particle Swarm Optimization

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ABSTRACT: *In this paper we are simplify the model of an islanded micro-grid systems using Single Perturbation method (SP) and Particle Swarm Optimization. The used model is of an 6th Order islanded micro-grid model. As we know it is not possible to approximate the dynamics of any system using slow subsystem, so we also obtain the result of slow subsystem in this paper. In this work, we presented two Model order reduction methods viz. Direct Truncation (DT) and Particle swarm optimization. Thus, sixth order has been reduced to the fourth order approximation. We have also presented the Particle Swarm Optimization (PSO) to reduce the model order to 2. Thus various responses have been compared. In the results, it has been shown that even with using 2nd order reduction using PSO, it shows the improved response than other methods***.**

Keywords: singular perturbation method, Direct Truncation, micro-grid, model order reduction.

1 INTRODUCTION

Smart grid are increasing in these days frequently, many research have been done on many areas like , control of grid system, safety regards of micro grids, smart operation of grids. As we know the interconnections of machine make the system is of higher order which create the large computational work and due to uncountable feedback loops , the system design become difficult. Hence order reduction technique become very useful to simplify the higher order system to low order system. It has also an advantage that it has not any significant effects on the properties of the system. Within a microgrid numerals order reduction have been employed and also for specific systems within it like , generators , renewable energy sources , controller design purpose .

In this paper we used a six order model of a Islanded micro grid system[7]. Two techniques have been discussed to simplify the dynamics , first is the singular perturbation method and second is Direct Truncation method. Direct truncation gives a good model match at high frequency , while singular perturbation methods have superior low frequency properties .Two different perturbation parameters have been used (Є=0)(Є≠0).

In this work, we have presented the Particle Swarm Optimization (PSO) method for model order reduction of 6th order to 2nd Order respectively. Thus, the various responses have been observed. It was found that it outperforms all the methods in terms of the output responses.

1.1 ISLANDED GRID SYSTEMS

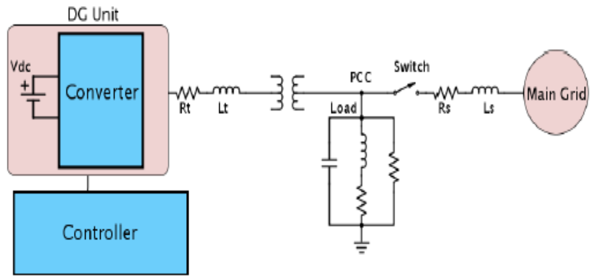

Fig.1. Model of an Islanded Grid systems

The system of Fig. 1 is required to operate in both the grid-connected and the islanded modes. In the grid-connected mode, the interface converter operates as a current-controlled VSC. Voltage magnitude and frequency of the local load (PCC) are dictated by the grid. A -frame current-control scheme is designed to control the power-exchange between the DG unit and the grid of Fig. 1. The grid can exchange real and reactive power with the potential island. When both real and reactive power exchange between the potential island and the grid are zero, the system operates in a matched power state.

Otherwise, the system is in a mismatched-power condition. When the DG unit and the local load are islanded by opening switch S, due to power mismatch between the load and the DG unit and in the absence of voltage and frequency controls, the PCC voltage and frequency deviate from their rated values.

Thus, voltage and frequency of the load can vary significantly if the DG unit does not provide voltage and frequency control. Therefore, to achieve uninterruptible autonomous operation of the island, the islanding event must be detected and subsequently voltage and frequency must be controlled. In this case, the new controller to be developed should regulate voltage magnitude and frequency of the load.

The design of this new controller is based on a dynamic model of the islanded system as discussed in the next section. The frequency of the islanded system is controlled using an internal oscillator in an open-loop manner. Frequency of the internal oscillator is set at the system nominal frequency.

1.2 Direct Truncation Model

$$\begin{bmatrix} z_1(t) \\ z_2(t) \end{bmatrix} = \begin{bmatrix} \mathrm{I} - \varepsilon \mathrm{HL} & -\varepsilon \mathrm{H} \\ \mathrm{L} & \mathrm{I} \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} = \mathrm{T} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix}$$

On the other hand, the response of the fast subsystem obtained via exact decoupling is almost identical to the response of the original system. The exact slow-fast decomposition is achieved by utilizing the Chang transformation as above.

1.3 Particle Swarm Optimization (PSO)

Particle Swarm Optimization simulates the behavior of a swarm i.e. a group of birds. It is a computational method that optimizes a problem by running several iterations until the optimal solution is obtained. This stochastic optimization technique based on population was developed by Dr.Eberhart and Dr. Kennedy in 1995.

It is a technique implemented in various applications in order to determine an optimum solution. It simulates the intelligent behavior of a group of birds moving from a place to their target. The birds adjust their velocity and speed to reach the target in accordance to their own position as well as neighbor's position closest to the optimum solution. Similarly, initial solutions assumed are moved around in a search space logically following the PSO algorithm in accordance with the particular application and varying various parameters to reach the optimum solution.

- PSO learned from the scenario and used it to solve the optimization problems [2].
- In PSO, each single solution is a bird in the search space termed as particles.
- Initially, depending on the application a search space is decided consisting of a number of solutions.
- Each particle's initial position and velocity is assumed.

Pseudo-code:

Equation (a)

v[ ] = c0 *v[ ]+ c1 * rand() * (pbest[ ] - present[ ]) + c2 * rand() * (gbest[ ] - present[ ])

Equation (b)

present[ ] = present[ ] + v[ ]

```
For each particle
   Initialize particle
END
Do
  For each particle
  Calculate fitness value
  If the fitness value is better than its peronal best
set current value as the new pBest
End
Choose the particle with the best fitness value of all asgBest
   For each particle
   Calculate particle velocity according equation (a)
   Update particle position according equation (b)
End
```

Parameters	Values
No of Swarm	40
Bird Step	40
Dimension	3
PSO Parameter C1	1
PSO Parameter C2	1
PSO Parameter C3	0.8

1.4 SIMULALTION PARAMETERS

Parameters	Symbols	Values
Resistance of VSC Filter	Rt	1.5 mΩ
Inductance of VSC Filter	Lt	300uH
VSC Rated Power		200 MVA
VSC Terminal Voltage		600V
Switching Frequency	f_{sw}	1980 Hz
DC Bus Voltage	v_{dc}	1500 V
Load Nominal resistance	R	56 Ω
Load Nominal Inductance	L	111.9 mH
Load Nominal Capacitance	C	120uF
Load Quality Factor	Q	1.83
Load Resonant Frequency	fres	273 Hz
Inductor Quality Factor	ql	753.36
System Nominal Frequency	f0	60 Hz
Transformer Voltage ratio		0.6/13.8 kV
Transformer rating		200 MVA

Here, all the parameters has been listed of the Islanded systems. The VSC parameters has been listed as Rt and Vt. The system has been designed for the 200MVA systems. The switching frequency has been used as 1980 Hz. Also, the Load has been presented as R = 56 Ohm, L = 111.9 mH, C = 120uF.

$$A = \begin{bmatrix} -\frac{1}{RC} & \omega_0 & \frac{1}{C} & 0 & -\frac{1}{C} & 0 \\ -\omega_0 & -\frac{1}{RC} & 0 & \frac{1}{C} & 0 & -\frac{1}{C} \\ -\frac{1}{L_t} & 0 & -\frac{R_t}{L_t} & \omega_0 & 0 & 0 \\ 0 & -\frac{1}{L_t} & -\omega_0 & -\frac{R_t}{L_t} & 0 & 0 \\ \frac{1}{L} & 0 & 0 & 0 & -\frac{\omega_0}{q_l} & \omega_0 \\ 0 & \frac{1}{L} & 0 & 0 & -\omega_0 & -\frac{\omega_0}{q_l} \end{bmatrix}$$

$$B = \begin{bmatrix} 0 & 0 & \frac{1}{L_t} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{L_t} & 0 & 0 \end{bmatrix}^T, C = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

2 RESULTS & DISCUSSIONS

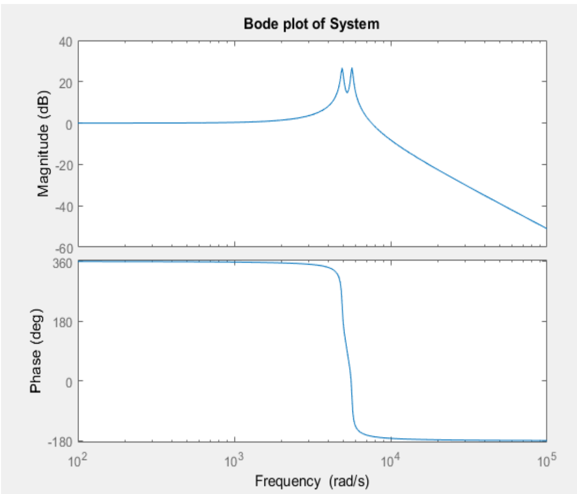

Fig.2 frequency Response of the original 6th Order system

Fig.2 Shows the frequency response of the original system. It follows the low pass system. It shows the higher order and lower order oscillatory behaviour. Our motive is to follow the same response through direct truncation method.

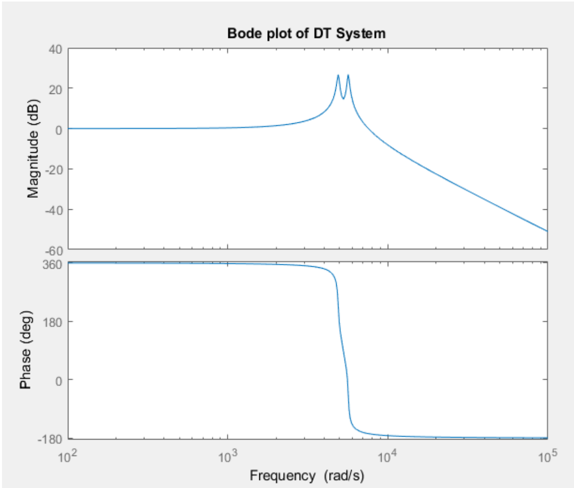

Fig.3 frequency Response of the reduced system transfer function of original 6th Order system

Fig.3 Shows the frequency response of the reduced order system. It has been shown that as per fig.3. the obtained reduced order system follows the similar response to that of the original system.

Now, since the original system resembles the MIMO system. Thus, reordering the same, we get two transfer functions H1 and H2. Thus here, both transfer function has been presented and their step response curve has been shown.

The transfer functions of the H1:

```
H1 =

  2.778e07 s^10 - 7.777e09 s^9 + 2.327e15 s^8 - 4.314e17 s^7 + 6.487e22 s^6 - 5.506e24 s^5 + 6.081e29 s^4

                                                       + 5.768e30 s^3 + 1.69e35 s^2 + 9.298e35 s + 1.192e40
 ----------------------------------------------------------------------------------------------------------------
 s^12 + 627.8 s^11 + 1.124e08 s^10 + 5.327e10 s^9 + 4.711e15 s^8 + 1.511e18 s^7 + 8.745e22 s^6 + 1.473e25 s^5

                                       + 6.144e29 s^4 + 1.136e31 s^3 + 1.694e35 s^2 + 1.322e36 s + 1.191e40
```

The transfer function of the H2:

```
H2 =

  2.778e07 s^10 + 3.411e10 s^9 + 2.343e15 s^8 + 1.928e18 s^7 + 6.544e22 s^6 + 2.736e25 s^5 + 6.111e29 s^4

                                                       + 1.5e31 s^3 + 1.698e35 s^2 + 1.585e36 s + 1.197e40
 ----------------------------------------------------------------------------------------------------------------
 s^12 + 627.8 s^11 + 1.124e08 s^10 + 5.327e10 s^9 + 4.711e15 s^8 + 1.511e18 s^7 + 8.745e22 s^6 + 1.473e25 s^5

                                       + 6.144e29 s^4 + 1.136e31 s^3 + 1.694e35 s^2 + 1.322e36 s + 1.191e40
```

Response of H1 and H2:

Step response of H_1 and H_2

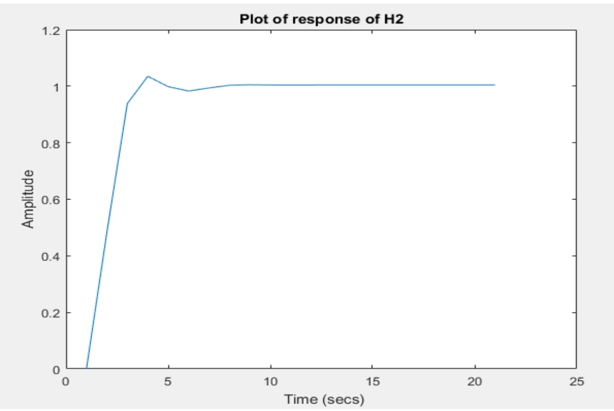

Fig.4 Step response of Original H2

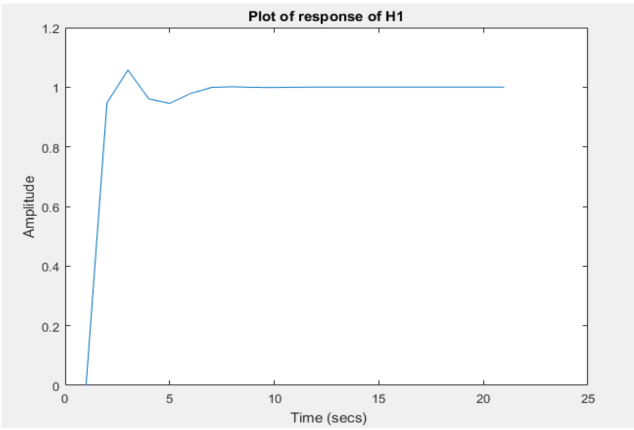

Fig.5 Step response of Original H1

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