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Implementation of LFC in Multi Area Power Systems using Conventional Controller

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Abstract: ***Nowadays bulk power system is consisted of multiple interconnected controllable areas. In Interconnected power system, small disturbance occurs in load at any areas that causes the fluctuation of frequency at each and every area. Also fluctuate the power flow between the different areas. So, the main objectives of LFC are to maintain the frequency to its nominal value and scheduled the power exchange between the areas. This can be achieved by the conventional controller.so here conventional PID controller used as a controller in two thermal and one hydro area interconnected power system. Make a MATLAB simulink for LFC in multi area interconnected power system. Analysis this system response with and without PID controller along with and without consideration of generation rate constraint.***

Keywords: load frequency control (LFC)scheme, Automatic generation control (AGC),, AC link parallel with DC link, Generation rate constraint, conventional PID controller

Nomenclature

F	Nominal System Frequency (Hz)
I	Subscript referred to area i (1, 2, 3)
Tti	Steam turbine time constant of area i (s)
Pri	Rated power of area i (MW)
Hi	Inertia constant of area i (s)
KPi, KIi, KDi	Proportional, Integral, and derivative gains of PID controller in area i
ΔPgi	Incremental generation change in area i (p.u)
Di	ΔPDi/Δfi (pu/Hz)
T12, T23, T13	Synchronizing coefficients
Ri	Governor Speed regulation parameter of area i
Tgi	Steam governor time constant of area i (s)
Kri	Steam turbine reheat coefficient of area i.
Tij	AC tie line time constant.
TDC	DC tie line time constant.
KDC	Feedback gain of DC tie line.
Bi	Frequency bias constant of area i.
Tri	Steam turbine reheat time constant of area i (s).
Tpi	2Hi / f* Di.
KPi	1/Di. (Hz/pu).
ΔPDi	Incremental load change in area i (p.u).
Bi	Area frequency response characteristics of area
Δfi	Incremental change in frequency of area i (Hz).
ΔPgi	Incremental generation of area i (p.u).
ΔPtieACi-j	Incremental change in AC tie line power connecting between area i and area j (p.u).
ΔPtieDCi-j	Incremental change in DC tie line power connecting between area i and area j (p.u).
Kd, Kp, Ki	Electric governor derivative, proportional, and integral gains respectively
Tcharge	Charging time constant of the BES.
Tconv	Time constant of the converter in BES.
KPB	Feedback gain of incremental change in BES power
ΔPB	Incremental change in BES power output.
KB	Feedback gain of frequency fluctuation in grid.
Pcal1-Pset1	Compensated power caused by ramp limitations of generators;
ACE	Area control error

1. Introduction

Nowadays most of power systems are interconnected with their neighboring areas. In a multi-area power system, every area has a various types of uncertainties and disturbances arising from complexity of the system, system modelling errors and changes in power system topology due to faults and switching. In interconnected multi area power system as a power load demand varies randomly, in the case of any small sudden systems are divided into various areas.In an interconnected multi-area power system, as a power load demand varies randomly, in the case of any small sudden load change in any of the areas, both area frequency and tie-line power flow interchange also vary. The main goals of Load

Frequency Control (LFC) are,

- Hold the frequency constant (f= 0) against any load change. Each area must contribute to absorb any load change such that frequency does not deviate.
- Each area must maintain the tie-line power flow to its pre-specified value.

Unbalance between supply and load causes the fluctuation of the system frequency, which can degrade the power system performance and makes his control more difficult. LFC has been one of the important control challenges in electric power system stability and control. Automatic generation control plays the major role to maintain system frequency at or very close to a specified nominal value and to sustain the scheduled exchange of power. Load Frequency Control is important to hold the system frequency and the inter-area tie -line power flow as near with neighbouring control areas at the scheduled values. In order to satisfy the LFC objectives, a control error signal named the area control error (*ACE*) is measured. This signal is a linear combination of net interchange and frequency deviation and represents the real power unbalance between supply and load of power. The area control error (*ACE*) is given by:

$$ACE = \Delta P_{tieij} + \beta_i \Delta f_i$$

2. Automatic Generation Control (AGC)

Load frequency control has a control feature in the speed governing linkage mechanism. AGC (automatic generation control), which have a speed governing linkage mechanism. In this mechanism if the generator speed is suddenly falls or exceeds to its nominal pre- specified value then the speed governor sense the speed of generator and it will adjust the steam/water which is given to the turbine. Because ultimately the electromagnetic torque which produced by the turbine is regulated then the generator speed and output power become regulate to its normal value. The main aim of load frequency control is to minimize the transient variations in these variables and also to make sure that their steady state errors is zero. Many modern control techniques are used to implement a reliable controller. The objective of these control techniques is to produce and deliver power reliably by maintaining both voltage and frequency within permissible range. There are various control strategies are used for proper control of load frequency are:

- I (integral) controller
- PI (proportional -integral) controller
- PID (proportional –integral-derivative) controller
- Artificial intelligent technique

In present work, conventional controller used is PID controller.

3. Generation Rate Constraint (GRC)

In general, there exists a minimum and maximum limit on the rate of change in the generating power (ΔP_G). Figure 3.16 shows, due to adiabatic expansion, sudden power decrease would draw out excessive steam from boiler system to cause steam condensation. The steam valve of high pressure turbine acts as a control valve associated with LFC.

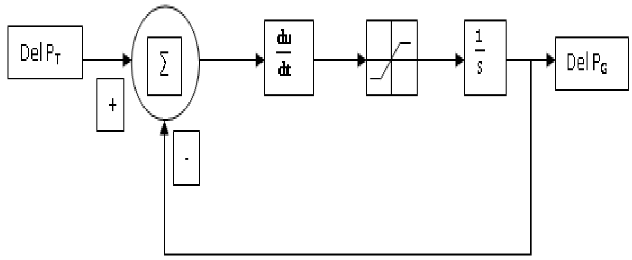

Figure 1: Block diagram represent the generation rate constraint

Three area interconnected power system:
Three interconnected area considered in this paper are:

Area-1 is reheat thermal plant Areaa-2 is also reheat thermal plant and Area-3 is hydro plant. All these three area are interconnected with tie line in hydro area the electrical governor is used.

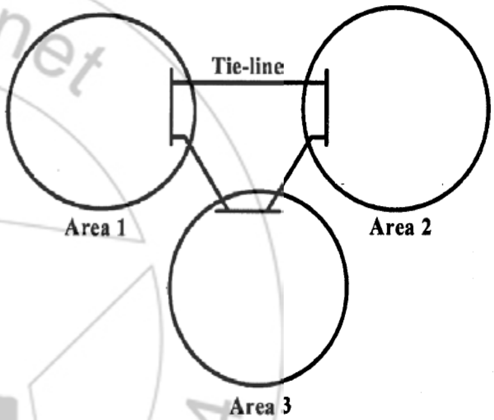

Figure 2: Three area interconnected power system

The complete block diagram of LFC in three area: In this system three area interconnected system is used. Conventional controller are also used to control the frequency at nominal value.

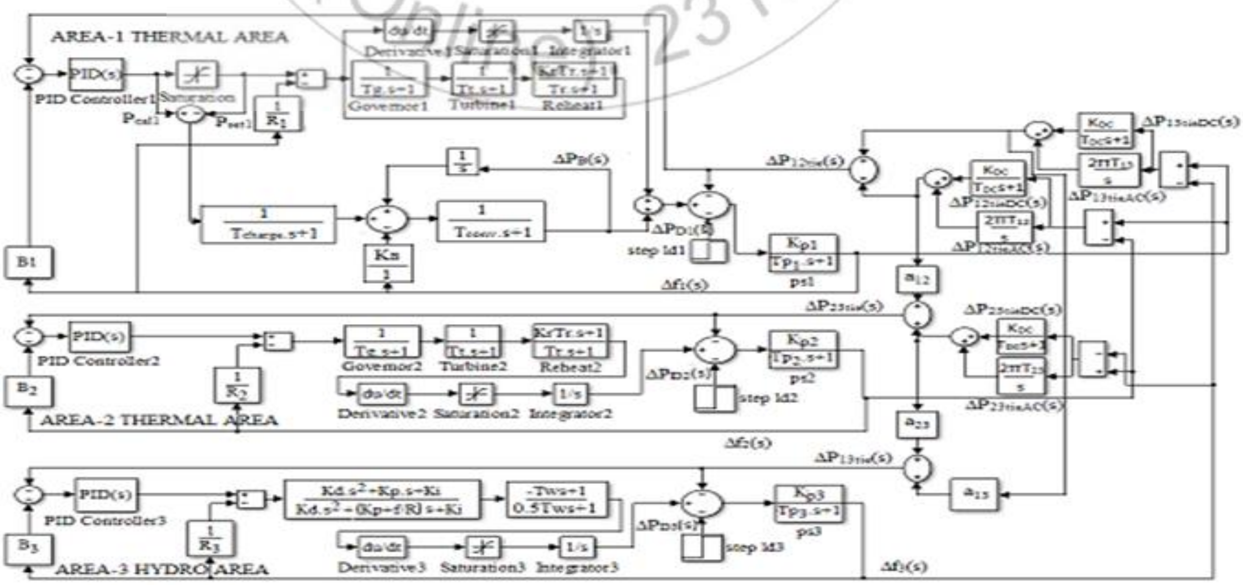

Figure 3: LFC in multi area power system

4. Results

Analyze the LFC in multi area power system response with and without PID controller along with and without consideration of generation rate constraint.

Without PID controller

After performing simulation in MATLAB software the result comes from the load frequency control in multi area power system without GRC as shown in figure below.

Frequency deviation:

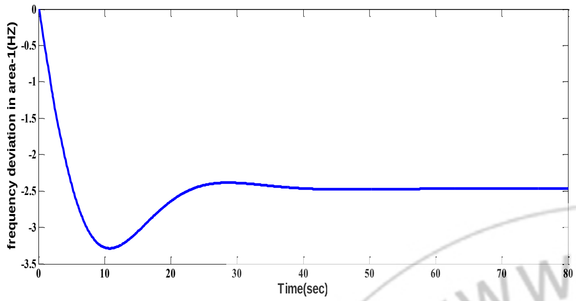

Figure 4: Open loop frequency deviation in area 1 without GRC.

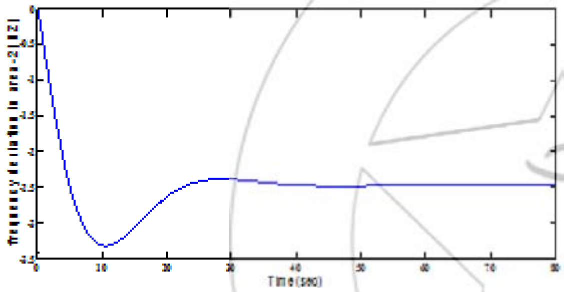

Figure 5: Open loop frequency deviation in area 2 without GRC.

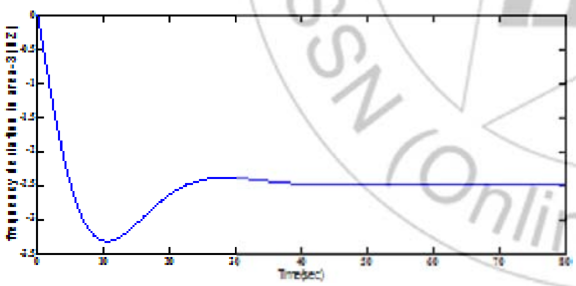

Figure 6: Open loop frequency deviation in area 3 without GRC.

Power deviation:

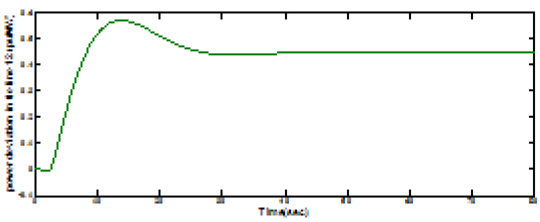

Figure 7: Open loop power deviation in tie line 12 without GRC.

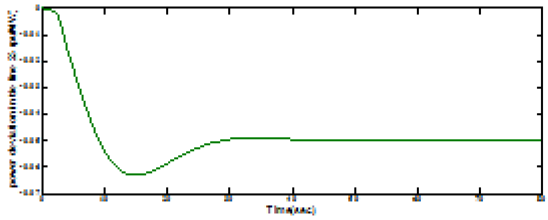

Figure 8: Open loop power deviation in tie line 23 without GRC.

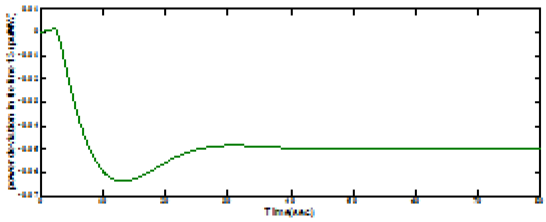

Figure 9: Open loop power deviation in tie line 13 without GRC.

With PID controller:

After performing simulation in MATLAB software the result comes from the load frequency control in multi area power system with GRC controller as shown in figure below.

Frequency deviation:

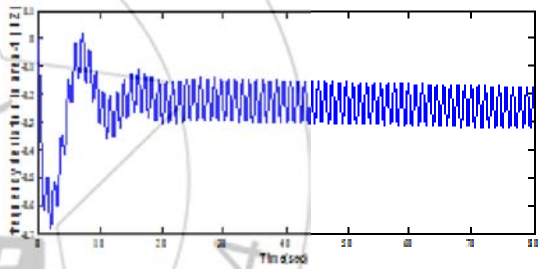

Figure 10: Open loop frequency deviation in area 1 with GRC.

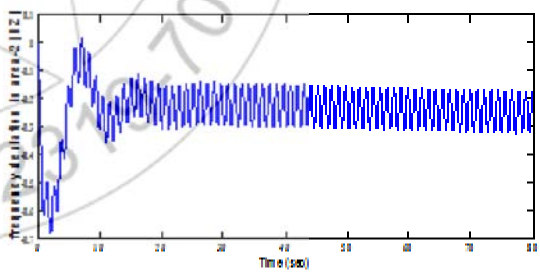

Figure 11: Open loop frequency deviation in area 2 with GRC.

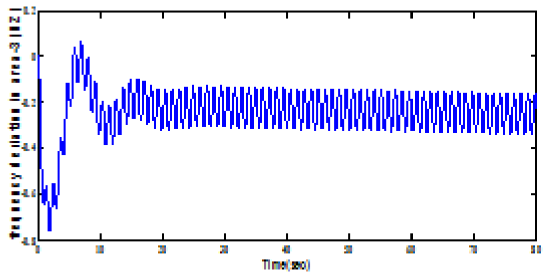

Figure 12: Open loop frequency deviation in area 3 with GRC.

Power deviation:

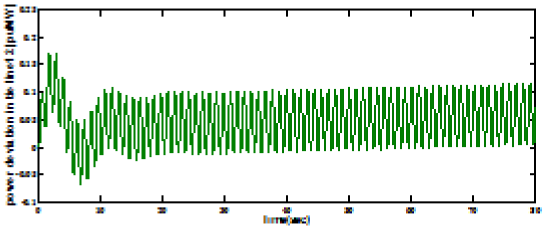

Figure 13: Open loop power deviation in tie line 12 with GRC.

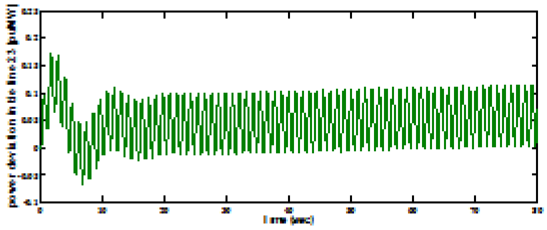

Figure 14: Open loop power deviation in tie line 23 with GRC.

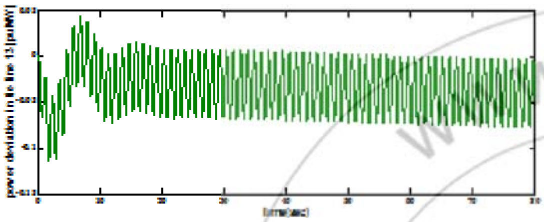

Figure 15: Open loop power deviation in tie line 13 with GRC.

With PID controller:

After performing simulation in MATLAB software the result comes from the load frequency control in multi area power system with GRC controller as shown in figure below.

Frequency deviation:

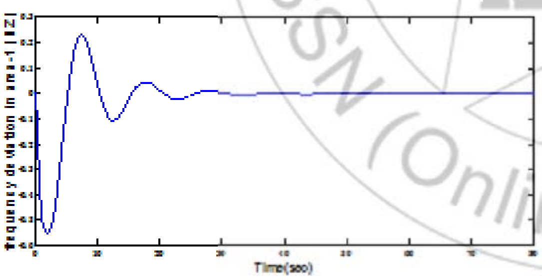

Figure 16: Close loop frequency deviation in area 1 with GRC.

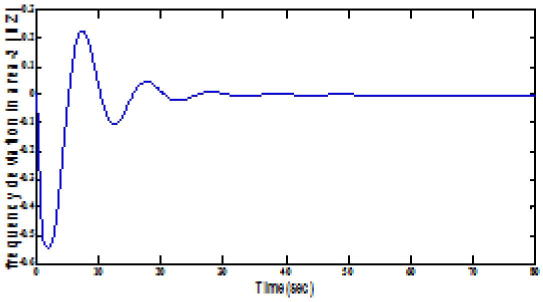

Figure 17: Close loop frequency deviation in area 2 with GRC.

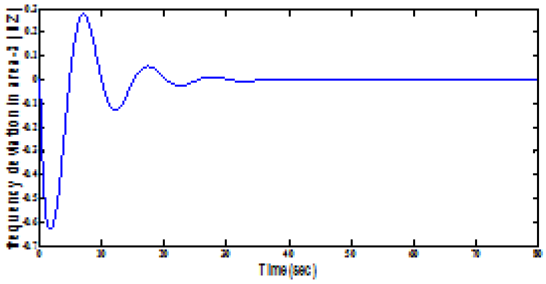

Figure 18: Close loop frequency deviation in area 3 with GRC.

Power deviation:

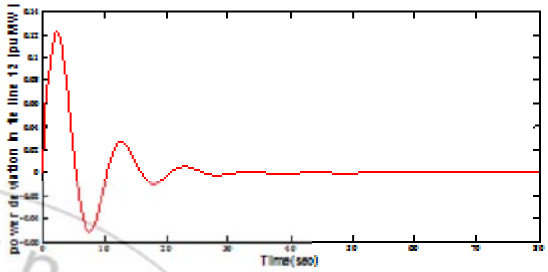

Figure 19: Close loop power deviation in tie line 12 with GRC.

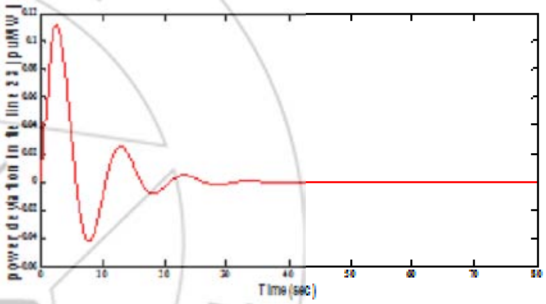

Figure 20: Close loop power deviation in tie line 23 with GRC.

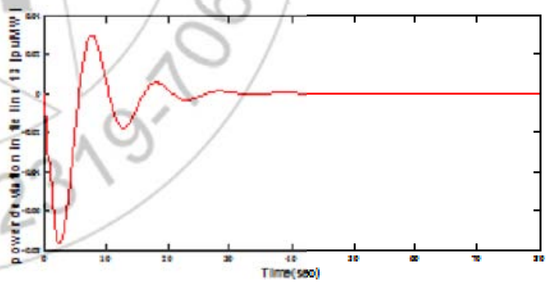

Figure 21: Close loop power deviation in tie line 13 with GRC.

COMPARISON OF WITH AND WITHOUT PID CONTROLLER:

Frequency deviation:

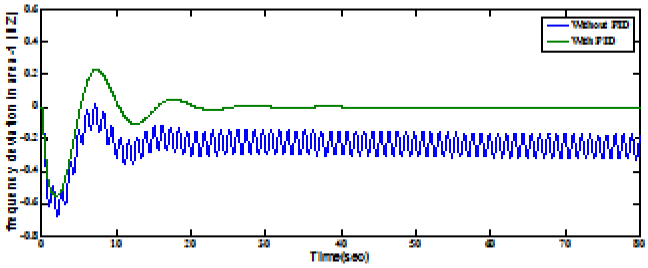

Figure 22: closed loop frequency deviation in area-1.

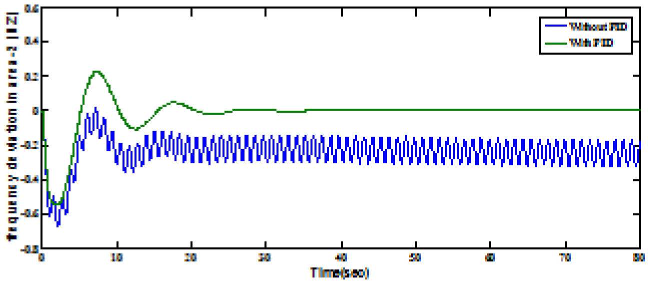

Figure 23: closed loop frequency deviation in area-2.

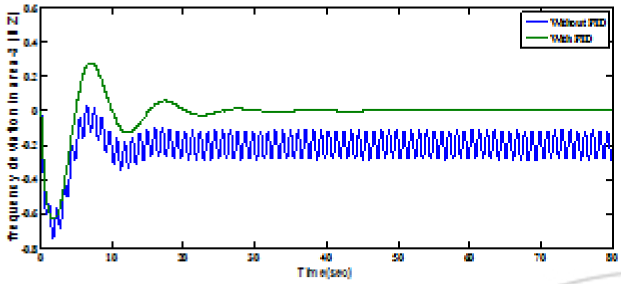

Figure 24: closed loop frequency deviation in area-3

Power deviation:

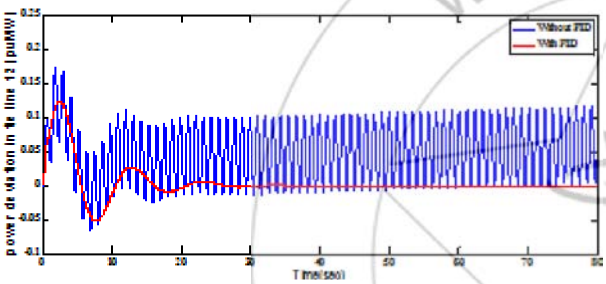

Figure 25: closed loop power deviation in tie line 12

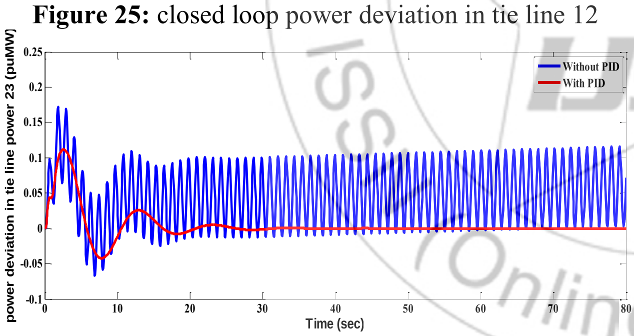

Figure 26: closed loop power deviation in tie line 23

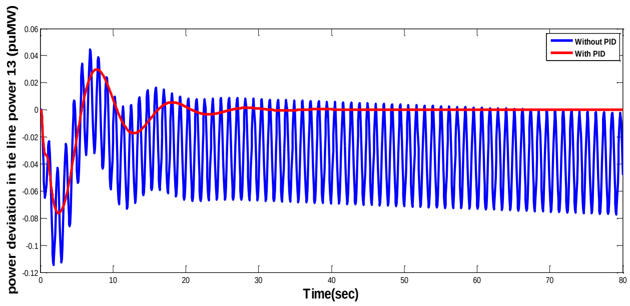

Figure 27: Closed loop power deviation in tie line 13.

5. Conclusion

The outcomes from study and after performing MATLAB simulink, the automatic generation control is used for regulate the frequency at nominal. And the AC tie line is use parallel with DC tie line. Because it improved the system parameter. And the disadvantages of AC tie line is overcome by using DC tie line. Also the LFC with generation rate constraint is used. Because the In general, there exists a minimum and maximum limit on the rate of change in the generating power (ΔPG). Due to adiabatic expansion, sudden power decrease would draw out excessive steam from boiler system to cause steam condensation. The steam valve of high pressure turbine acts as a control valve associated with LFC. And without GRC get less frequency fluctuation than with GRC but this fluctuation not like in practical actual system. Conventional controller is also used for scheduled the power and frequency. Here seen that the LFC with PID controller is better than without PID controller.

System nominal parameter:

f=50HZ,$R_1=R_2=R_3=2.4$,Tg=0.08,Tt=10,Kr=0.5,$P_{r1}=2000$,$P_{r2}=6000$,$P_{r3}=12000$,$a_{12}=-1/3$,$a_{23}=-1/2$,$a_{13}=-1/6$, $T_{12}=T_{23}=T_{13}=0.086$,$K_{p1}=K_{p2}=K_{p3}=120$,$T_{p1}=T_{p2}=T_{p3}=20$,$T_{DC}=0.03$,$K_{DC}=0.5$,Tw=1

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