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# PROPERTY OF ANCILLARY SERVICE MARKETS ON FREQUENCY CONTROL PERFORMANCE OF POWER SYSTEMS

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**ABSTRACT**: *In this Paper I have accessible different ancillary service markets for frequency control and analyze the result of such markets on the control presentation of power systems. Primary I have formed different market structures for harmonizing markets. Since the mechanical generation control to control frequency is quite standardized, I do not modify the control but only the market structures and study their result on frequency control presentation. I have tried to express that by altering the market structure and incorporate generator access ramp rates into the market intend, a new attractive control presentation can be achieved.*

**KEYWORD**: *Ancillary market, Frequency control, Harmonizing market, power system*

## INTRODUCTION

Instruction is one of the ancillary services (AS) usually provided by the generating units, under the authority of a harmonizing area, to repetitively pay off for the disparity sandwiched between load and generation. Subsequent to the initiation of deregulation, there has been a large amount attempt to form spirited markets for parameter. These markets have regularly been markets for capacity reserves and have variously been described instruction, harmonizing, load-following, frequency control or even mutual with spinning reserve markets. For simplicity we identify it the regulation market during this paper. While the method of frequency control and load following has to be specifically defined surrounded by an interconnection, the structures of the instruction markets vary deeply. In North America, some regulation reserve markets have been urbanized for resultant control. The compensation is for capacity made obtainable, up and down, fully dispatch able surrounded by 10 minutes , the energy make available being rewarded at spot market charge. There is no undo regulation market and division of the spinning reserve is used for secondary rate of recurrence control in some areas l. In England and Wales, where mechanical secondary control is not used, there is a power exchange system with a 30-minute short-term market for harmonizing, operating one hour to the lead of actual time. There, only a few generators are called upon for frequency response replacing free regulator action by all generators. Similarly, regulation markets survive in Australia, Nordic countries, continental Europe, China and other countries; however, the frequency presentation values are prejudiced heavily by regional policies and grid regulations

### Objective

In this paper I have alert my consideration on harmonizing markets, which includes regulation and load subsequent, and resulting voltage control markets to analyze the outcome of poles apart markets for these ancillary services on control presentation of the power system. The primary objective is out of order into the ensuing subtasks:

- Studying the existing frequency and markets and the measure of control presentation

- Identifying the attributes that influences control performance of the system and achievable improvements

Ancillary services

Ancillary services are those essential to preserve the fundamental function of power systems provided by generators and transmission control tools. While the number of approaching services is huge, the subsequent services are predictable in the most important power systems as ancillary services and are asked from those who are accomplished of on condition that them:

- Energy inequality equalization
- Frequency guideline
- Spinning reserve production
- Extra reserve production
- Reactive power abounding from generators
- Black start

The purpose of the frequency guideline service is to preserve the frequency of the system at the meticulous charge. At the spirit of frequency regulation is the mechanical Generation Control. When on gravel there is an arbitrary discrepancy in system load, the frequency and tie line interchanges move away from its planned value. It is the AGC/ mechanical Generation Control that wits the deviations and brings the values of frequency and tie line interchange back to standard by re-dispatching the generators under control for protected operation of the power system. The purpose of secondary voltage control is to preserve the voltage over the network controlled these limits by supervision the reactive power supplied by generators. Inside a deregulated upbringing generation, transmission and distribution systems are owned by separate organizations. Spirited markets have been urbanized where Load Serving Entities (LSE) can obtain energy from Independent Power Producers (IPP).

**Regulation Market**

All markets can be considered with many divisions and regulation markets are the equal. To illustrate how such divisions can influence system presentation we first lay out the structure of three example regulation markets in this section. These three are briefly described below.

Firstly, the flat-rate regulation market – This is the most frequent type of regulation market that exists. The facial appearances are as follows:

- 10-minute regulation market and any spinning unit under AGC control can bid the capability it can be made obtainable in 10 minutes.
- No division according to ramp rates of the generators.
- Consistent second price payment, all eligible suppliers will be paid at the rate of Market Clearing Price (MCP).

Secondly, a price based regulation market – The generators will be rewarded based on the presentation in the market.

- 5-minute otherwise 10-minute regulation market
- Generators can be categorized as high-speed or deliberate as per the ramp rates.
- The high-speed ramp generators can be paid according to the regulation MCP whereas deliberate ramp generators are paid according to their bid price as long as it is a lesser amount of than the regulation MCP

Finally, a reaction based regulation market – Two separate markets for high-speed ramp regulation and intentional ramp regulation.

- 5-minute market for high-speed ramp regulation
- 10-minute market for deliberate ramp regulation.

- Generators will acceptable to partake in the individual market which its ramp rate corresponds toward.
- Generators can be paid at the rate of clearing price of the market they partake keen on.

All the generators will be participating in the regulation markets mentioned more than are essential to assemble convinced mechanical and operating supplies. Primary control by governor action is binding for contribution. The full reaction of the bid capacity is obligatory to be delivered in the transmit period (10 or 5 minutes as appropriate). As a result the regulation bid capability of each supplier will be needed on its ramp rate. This last point is incredibly imperative since this establishes the correlation amid market outcome and subsequent control presentation.
To bid (Figure1) in the markets, each provider specifies three quantities in the bid: 1) capacity, 2) price in $/MWh, and 3) prepared ramp rate in MW/min. The markets can be cleared for every dispatch period during the trading period to the front of real time. The market can be formulated as single public sale power pool (Figure 2) where only suppliers bid in the market otherwise twice auction power pool, where suppliers' bids will be cleared adjacent to customers' offers. I receive for granted single Dutch auction pool for all markets painstaking

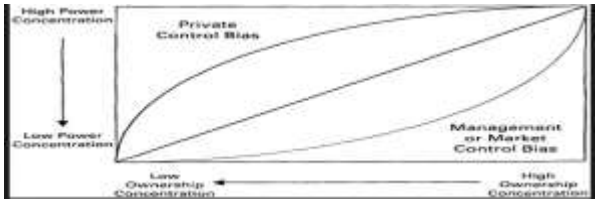


Figure-1: Regulation market bid.

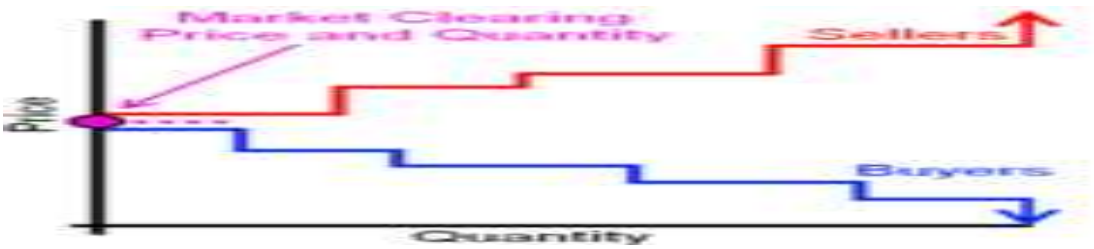


Figure -2: Market clearing in single auction pool

Firstly, the flat-rate regulation markets are the most in a straight line to the fore and followed at several spaces of North America and North Africa. The simple scenery of such a market makes it prominent; however there is good rationale for suppliers not to partake in such market as it does not differentiates along with the participants and pays a flat price irrespective of their presentation. Secondly, a price based regulation market on the other hand over solves that difficulty and introduces the performance based Pricing. The competent generators are taken delivery of market payment at the rate of their bid price apart from the high-speed ramp generators which are paid at the rate of MCP. Since the MCP is the highest probable payment accessible in auction market, recipients get absent with a quantity of motivation for their service. Finally, a reaction based regulation market is to some extent similar to the eventuality preserve market, only the control here is on a longer moment in time edge. The partition of high-speed and deliberate ramp generators makes it potential to call upon the suitable service depending on the amount of the commotion. It is also possible to use a amalgamation of these services for asking price effectiveness. There is no need of additional inducement since break up markets would take care of it repeatedly.
Frequency Control

The activity of the regulation market is to decide on a set of generators to make available the service and to distribute the quantity of regulation apiece are hypothetical to provide at the point of require. The real-time regulation would be presented by Automatic Generation Control (AGC) to remain the frequency of the system surrounded by protected operating restrictions and the interchanges flanked by the areas at the planned assessment.

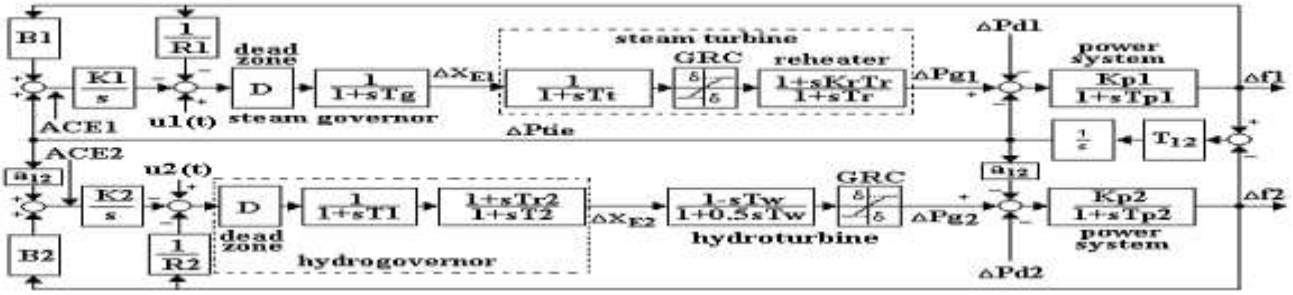


Figure -3: Classical AGC for two control areas

For the function of modeling it is implicit that the generators in a control area are attached mutually strongly, electrically. As a result they vacillate together under small disturbances. If the departure in frequency and load are petite sufficient, each control area can represented as the linear estimate as shown in the Figure -3.at the same time as modeling the personality generators (Figure -4), it is to be remembered that there are restrictions on the velocity at which generators can move their output due to thermal and mechanical stress on the tools. The ramp rate of hydro units are of the order of 100% of the rated capability within proceedings. However, the ramp rates of thermal units are imperfect and thermal turbines can be approximated as shown in Figure -5

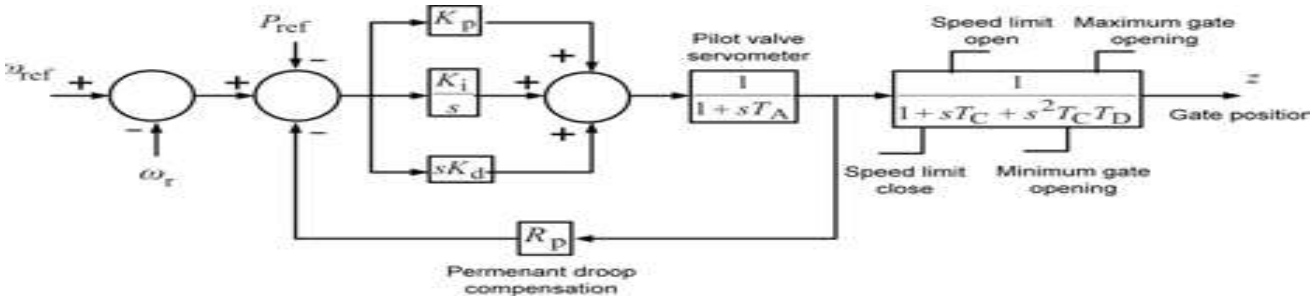


Figure -4: Model of generator with classical AGC

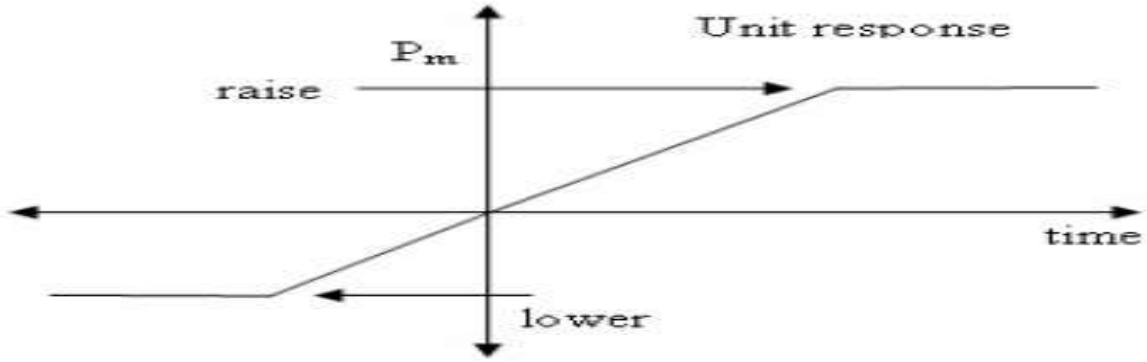


Figure -5: Output of rate limited units

We define the performance vector η to convey the frequency control presentation of the markets described previous as:

$$\eta = \begin{bmatrix} \Delta f_{max} \\ t_s \\ t_c \end{bmatrix}$$

Where, $\Delta f_{max}$ is the highest deviation of system frequency after the disturbance, $t_s$ , settle time is the time in use by AGC to bring the frequency back within safe limits, and
$t_c$ , intersect time is the time in use by ACE to fractious zero for the first time after the disturbance
Case study Impact of ancillary service frequency control .

The projected market has simulated on a condensed WECC model with 225 buses where the California ISO (CAISO) and LADWP are represented in additional element than the respite. The network has been separated into three harmonizing areas (BA1 to BA3), which are summarized below in Table 2-I. All three areas are consistent to each other with tie lines. The market is lay down up area BA3 where all of the 40 generators suggest their bid in the regulation market. The market target is to secure 650MW up and 250MW down regulation capability at a total load of 25500MW for the hour. The bid prices will be Obtained from the generator charge curves which are of the form $C(P) = a+bp+cP^2$ and the dispatch rank as per the Optimal Power Flow (OPF). It can be related to point out here that in authenticity the bids submitted by the Participants depend on a big amount of market factors. Moreover, the imbursement of bid price as a substitute of the clearing price may modify the way suppliers submit bids. Our supposition of bid value creature same as the marginal cost of generation irrespective of the market is exclusively to present a proportional idea about the impact of dissimilar market structures in a common structure.

**Market Settlement**

i) flat-rate regulation and price based regulation 10-minute markets.

The upshot of resolution for 10-minute regulation market of flat-rate regulation and price based regulation market is identical as far as the generators and constricted quantities are disturbed. As predictable the market payment for price based regulation is less than that of flat-rate regulation market. The ultimate contract is revealed in
Table I. It can be practical that the procurement resulted in 6 contracts; the useful ramp rate of the system is 65 MW/min.

Table -I: Summary of control area parameters

| Area code | No. of generators | H (p.u) | D (% per 1% f) |
|---|---|---|---|
| BA1 | 13 | 1685 | 1.06 |
| BA2 | 9 | 637 | 0.26 |
| BA3 | 40 | 1076 | 0.91 |

ii) Price based regulation 5-minute market

The resolution of the Price based 5-minute regulation market is shown in Table 2-III for the identical market target. 15 generators are constricted for regulation which is perceptibly superior to the previous container. The reason of superior number of generators being established in a 5-minute market is outstanding to the reality that in a market with shorter dispatch period the generators are capable to bid a smaller quantity for a specified ramp rate. The effective ramp rate for the scheme consequential from the market is 140 MW/min.

Table 2: 10-min market – Regulation contracts and prices

| Gen# | Cost of generation (c, b, a) | Contracted Regulation | |
|---|---|---|---|
| | | Up/Down (MW) | Ramp rate (MW/min) |
| 6 | (0.00378, 20, 0 ) | 70, 0 | 7 |
| 8 | (0.00224, 20, 0 ) | 90, 0 | 10 |
| 15 | (0.00343, 20, 0 ) | 80, -80 | 8 |
| 16 | (0.00768, 20, 0 ) | 80, -80 | 8 |
| 17 | (0.00193, 20, 0 ) | 200, -40 | 20 |
| 20 | (0.030600, 20, 0) | 80, 0 | 8 |

| ISO's burden from these contracts | |
|---|---|
| Total payment | Type A: 23226.00 $/h |
| | Type B: 23113.20 $/h |
| Clearing Price Up | 38.71 $/MWh |
| Clearing Price Down | 22.03 $/MWh |

iii) Reaction based regulation market

Reaction based regulation market is contained of a 5-minute high-speed ramp market and a 10-minute deliberate ramp market. The markets are established unconnectedly each procuring half of the regulation target. The disconnect markets for high-speed ramp regulation and deliberate ramp regulation are shown in the Table -3 and Table -4. The two markets individually consequence in 8 contracts and full amount market imbursement is 23200.50 $/h.

Table -3: 5-min market – Regulation contracts and prices

| Gen# | Cost of generation (c, b, a) | Contracted Regulation | |
|---|---|---|---|
| | | Up/Down (MW) | Ramp rate (MW/min) |
| 4 | (0.00487, 20, 0 ) | 100, 0 | 20 |
| 5 | (0.00591, 20, 0 ) | 15, 0 | 3 |
| 6 | (0.00378, 20, 0 ) | 35, 0 | 7 |
| 8 | (0.00224, 20, 0 ) | 30, 0 | 10 |
| 9 | (0.00223, 20, 0 ) | 30, 0 | 6 |
| 15 | (0.00343, 20, 0 ) | 40, -40 | 8 |
| 16 | (0.00768, 20, 0 ) | 40, -40 | 8 |
| 17 | (0.00193, 20, 0 ) | 100, -100 | 20 |
| 20 | (0.0306, 20, 0) | 40, -20 | 8 |
| 23 | (0.00395, 20, 0 ) | 40, 0 | 8 |
| 24 | (0.00222, 20, 0 ) | 25, 0 | 5 |
| 25 | (0.01017, 20, 0 ) | 40, 0 | 8 |
| 28 | (0.00595, 20, 0 ) | 30, 0 | 6 |
| 29 | (0.00769, 20, 0 ) | 20, 0 | 20 |
| 35 | (0.04504, 20, 0 ) | 15, 0 | 3 |

| ISO's burden from these contracts | |
|---|---|
| Total payment | 23541 $/h |
| Clearing Price Up | 39.70 $/MWh |
| Clearing Price Down | 22.03 $/MWh |

It is significant to note here that the integer of constricted generators changes as the market structure changes. The correctness of any meticulous market model for a region depends on certain factors. Separately from economic policies mandated by the market operator and dictatorial association, accessibility of property and motivation of Suppliers would engage in recreation a vital role to fix on the right choice of market for a meticulous region. It be capable of seen by comparing the 5-minute and 10-minute markets of flat-rate regulation and price based regulation that a shorter dispatch period consequences in an increase in the number of generators participating in AGC. Now, a direct

obstruction to form a 5-minute regulation market may basically be bid shortage, since everyone bids into the market only what they can distribute in 5 minutes. In such a scenario a sensible choice would be to keep a 10-minute market in general and add a quality to the single market's regulation price for capability that can be delivered in 5 minutes.

Table-4: 5-minute fast ramp regulation market

| Gen # | Cost of generation (a, b, c) | Contracted Regulation Up/Down (MW) | Contracted Regulation Ramp rate (MW/min) |
|---|---|---|---|
| 4 | (0.00487, 20, 0 ) | 100, 0 | 20 |
| 8 | (0.00224, 20, 0 ) | 30, 0 | 10 |
| 17 | (0.00193, 20, 0 ) | 100, -100 | 20 |
| 30 | (0.00600, 20, 0 ) | 70, 0 | 20 |

| ISO's burden from these contracts | |
|---|---|
| Total payment | 11700.30 $/h |
| Clearing Price Up | 39.70 $/MWh |
| Clearing Price Down | 22.03 $/MWh |

Table-5: 10-minute slow ramp regulation market

| Gen# | Cost of generation (a, b, c) | Contracted Regulation Up/Down (MW) | Contracted Regulation Ramp rate (MW/min) |
|---|---|---|---|
| 6 | (0.00378, 20, 0 ) | 60, 0 | 3 |
| 15 | (0.00343, 20, 0 ) | 80, -80 | 8 |
| 16 | (0.00768, 20, 0 ) | 80, -20 | 8 |
| 20 | (0.0306, 20, 0) | 80, 0 | 8 |

| ISO's burden from these contracts | |
|---|---|
| Total payment | 11500.20 $/h |
| Clearing Price Up | 38.71 $/MWh |
| Clearing Price Down | 22.03 $/MWh |

Presentation contemplation

Generators preferred in the market as described over make available regulation and the AGC assigns regulation load to each preferred generator according to some predetermined involvement factors (pf) or regulation factors. There can be four ways to conclude these involvement factors.

- equivalent involvement factor for all units
- comparative to ramp rate of the units
- comparative to bid capability of the units
- Inversely comparative to marginal cost of generation

The following cases express ways to conclude involvement factors and consequent system response for a load disturbance of 1 p.u in BA3.

i) Flat-rate regulation and price based regulation 10-min markets 10-minutes markets of in cooperation Flat-rate regulation and price based regulation have fundamentally equivalent presentation for the motivation that the constricted generators are equivalent in both cases. Depending on the method of influential the regulation involvement the system response can show a discrepancy. The subsequent Table-6 summarizes the reaction of 10-minute market with four control schemes mentioned over that desire the involvement factors in a different way.

Table-6: Performance comparison of four controls

| involvement | $\Delta f$ (%) | $t_s$ (s) | $t_c$ (s) |
|---|---|---|---|
| Equal | -0.1445 | 350 | 112 |
| Ramp rate | -0.13 | 185 | 96 |
| Bid capacity | -0.13333 | 225 | 92 |
| 1/Marginal cost | -0.14167 | 350 | 110 |

Conspicuously, frequency response is best when the involvement factors are comparative to ramp rate. The explanation is, with such involvement factor every generator is stimulated by an amount which is identical to (ramp rate × dispatch interval).

ii) Price based regulation 10-min & 5-min markets

The special dispatch interval of the markets product in a differentiation in quantity of generators constricted and quantity of service bought from each of them. Flat-rate regulation 10-minute market yields 6 contracts while a 5-minute market yields 15 contracts. As a result the valuable ramping capability of the system is superior subsequent to the afterward comes into consequence. As be capable of be seen from the Figure -6, Figure -7, Figure -8 and Figure -9, the frequency response of the 5-minute market is quicker for all the four involvement methods. The overall that a generator can bid in the market depends on the ramp rate of the generator. In glasses case each generator gets its occupied bid capability conventional in the market, 2nd and 3rd involvement factors are basically same. But a generator's bid may be partly established in the market. In that case the control system with 2nd involvement method would be dissimilar than 3rd participation method

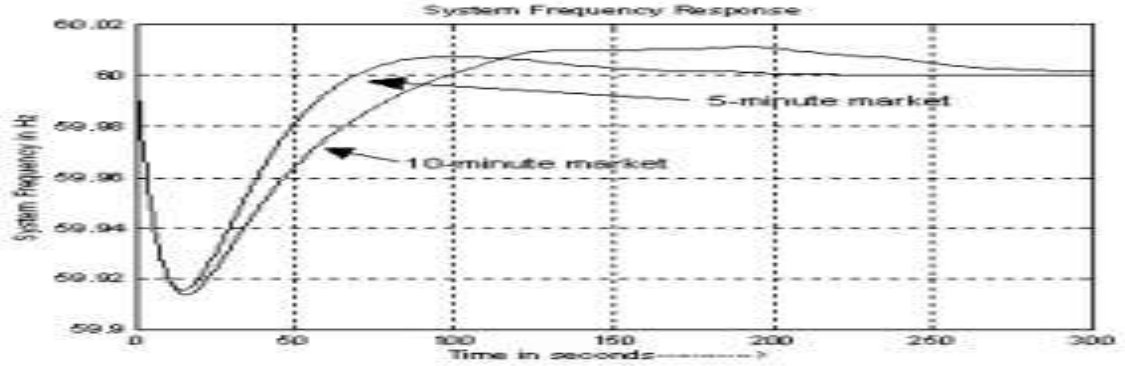


Figure -6: Frequency response with equal pf

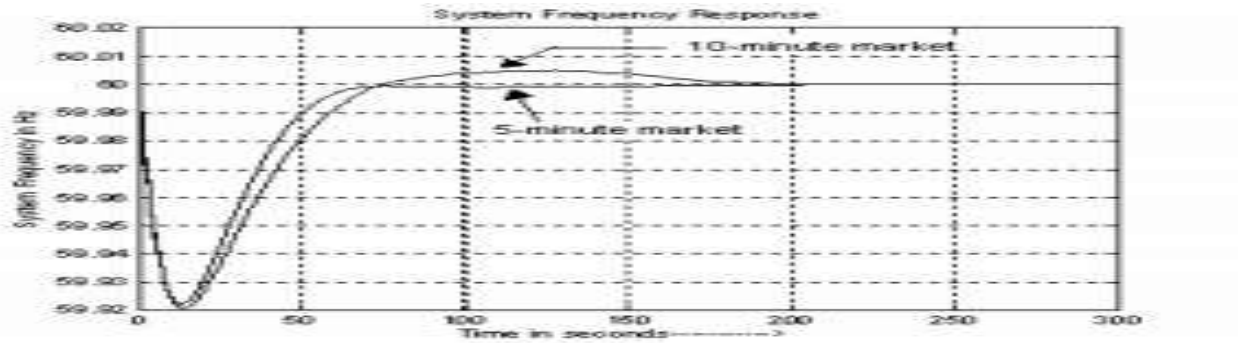


Figure -7: Frequency response with pf proportional to ramp rate

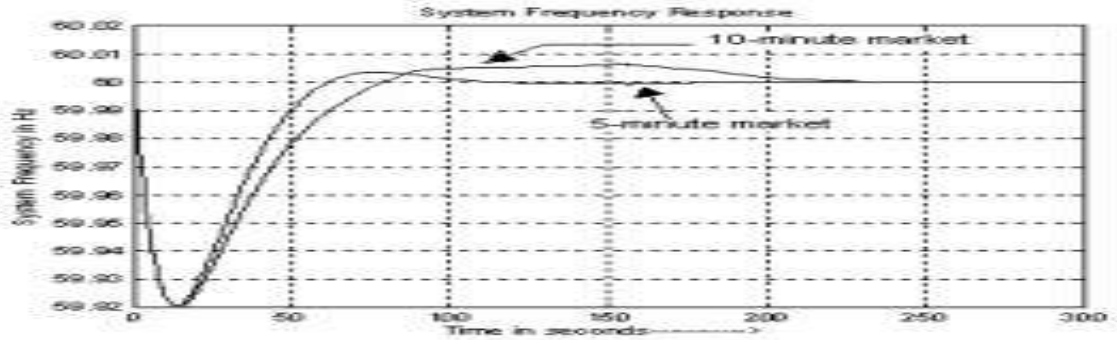


Figure-8: Frequency response with pf proportional to bid capacity

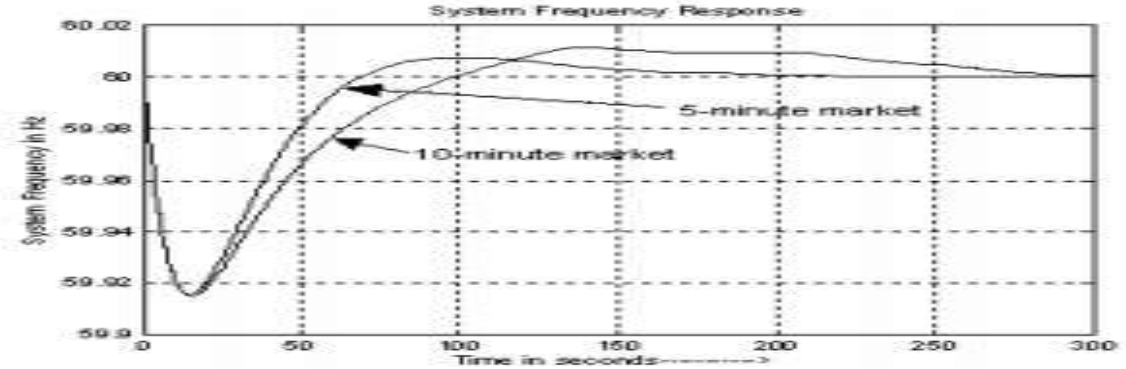


Figure -9: Frequency response with pf inversely proportional to marginal cost

The Table-7 shows the summary of the effect of four involvement methods on a 5-minute market.

Table -7: presentation comparison of four controls

| involvement | $\Delta f$ (%) | $t_s$ (s) | $t_c$ (s) |
|---|---|---|---|
| Equal | -0.14167 | 220 | 76 |
| Ramp rate | -0.13 | 150 | 100 |
| Bid capacity | -0.13333 | 175 | 76 |
| 1/ Marginal cost | -0.14167 | 221.1 | 78 |

The intersect time is significant in systems where ACE is predictable to modify signs within a positive time. In North America, NERC imposes arithmetical limits on the assessment of ACE and the operator is accountable to preserve the values within these restrictions.

iii) Reaction based regulation market

Contrasting the preceding two markets, Reaction based regulation market has disconnect markets for high-speed ramp and deliberate ramp regulation. To obtain a certain amount of regulation from such a market one has to make a decision how much of high-speed and deliberate service are to be bought. Then there are manifold options obtainable as to how to use them in time of necessitate. For the purpose of our study we have procured half of the regulation from each of the high-speed and deliberate markets. While using the possessions to follow the load we have looked into four scenarios using:

- high-speed ramp only
- deliberate ramp only
- high-speed and deliberate together
- Immediate use of high-speed, then deliberate service

For a load disturbance of 1p.u, it is probable to convey the frequency back to standard with high-speed generators alone, as shown in Figure -10 and Figure -11a.

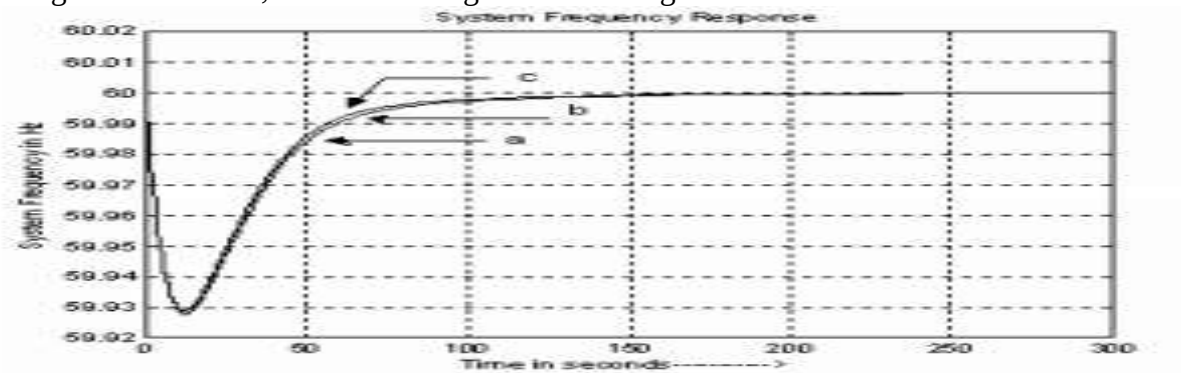


Figure -10: Regulation response with fast generators only with: a. Equal involvement, b. Ramp rate based involvement, c. Bid capability based involvement

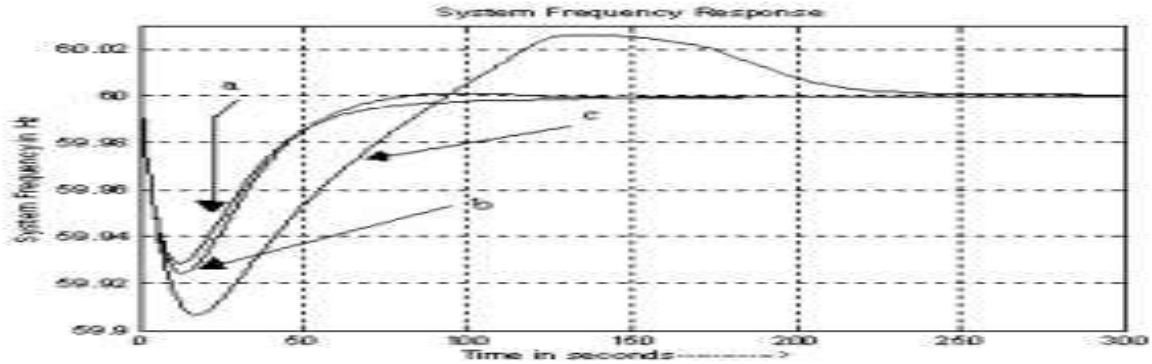


Figure -11: Regulation response with a. only fast, b. 50-50 high-speed & deliberate, c. only slow generators

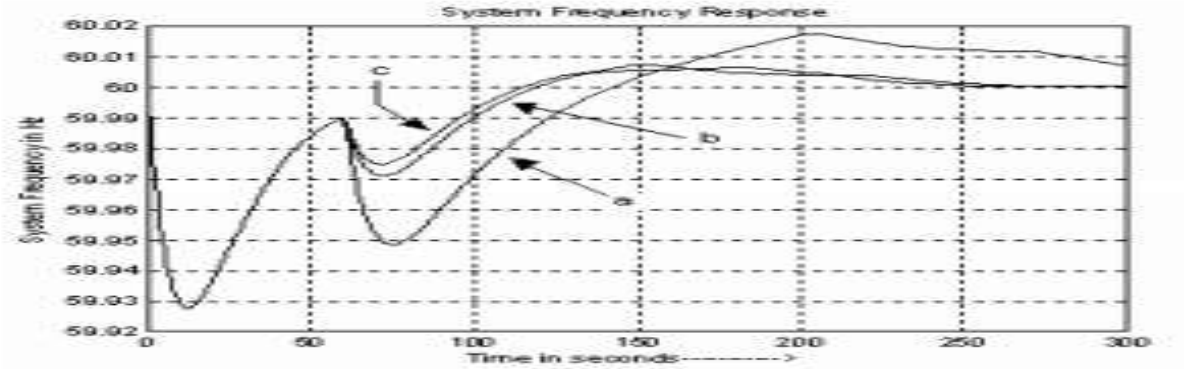


Figure -12: Regulation with high-speed response for 1minute and thereafter, a. deliberate only response b. 25% high-speed–75% deliberate amalgamation, c. 50% high-speed–50% deliberate response

If simply on purpose generators are used as a substitute, the recuperation of frequency is very deliberate and takes a long time to straighten out .But mutual jointly the high-speed and deliberate generators can pull through the frequency rapidly and effortlessly .The latter response is approximately the same as in Figure -11. Which only uses the high-speed response generators? In a typical case the operative may not wish to wear out the high-speed service totally and describe the sluggish resources to take up the residual of the regulation load. Though the high-speed market is intended to maintain the service for 5 minute, for the reproduction purposes some part of the high-speed resources are reassured after 1 minute of the incidence of the trouble. Figure -12 shows that a.

if only slow generators are used for regulation after 1 minute the frequency response is moderately deliberate, price based and reaction based regulation market if a combination high-speed and deliberate generators are used, is probable the pull through the frequency within the dispatch period. The response of case recreation based regulation market is smoother than that price based regulation market, Because of more speedy generators.

## CONCLUSION

In this work I have verified that the structure of ancillary service markets influence system presentation. Those ancillary services that present are in command of, like the regulation market to control frequency predominantly significant to intend properly so that the desired control presentation is obtained at the most excellent value. These resources are presented the structure of the ancillary markets should be such that individuals generators that can make a payment more towards improved control should be confident by the appropriate incentives. In the case of the regulation market this more often than not resources the acknowledgment that generating units with quicker response (ramp) rates are more important to load complementary and frequency control. I decide a simple experiment to show that the regulation market has a direct result on the control presentation of the system. Three different market structures were selected to display the anecdotal control performance on a reduced WECC model: the earliest is analogous to what is used by the California ISO today but the other two were chosen rather arbitrarily to provide more incentives for generators with improved response (ramp) rates. In the second structure we develop a second bid market for 5-minute capacity in totaling to the existing 10-minute capacity market. The 5-minute market preserve be used for better control than the 10-min market and at the same time these quicker generators can be satisfied with higher prices. In the third structure we form divide markets for high-speed and deliberate units based on ramp rates.

## REFERENCES

[1] I. Arnott, G. Chown, K. Lindstrom, M. Power, A. Bose, O. Gjerde, R. Morfill, N. Singh, “Frequency control practices in market environments”, Quality and Security of Electric Power Delivery Systems 2003, CIGRE/IEEE PES International Symposiumpp. 143 – 148, October 2008

[2] M. Ilic´, P. Skantze, C. N. Yu, L. Fink, J. Cardell, “Power exchange for frequency control (PXFC),” Proceeding of the 1999 IEEE PES Winter Meeting, pp. 809–819, February. 2009.

[3] J. Kumar, K. H. Ng, G. Sheblé, “AGCsimulator for price-based operation—Parts I–II”, IEEE Trans. Power Systems, vol. 12, no. 2, pp. 527–538, May 20077

[4] R. D. Christie, A. Bose, “Load frequency control issues in power system operation after deregulation,” IEEE Trans. Power Systems, vol. 11, no. 3, pp. 1191–1200, August 2006

[5] California Independent System Operator, “Business practice manual for market instruments”, version 2.0, January 2007, available at http://www.caiso.com

[6] K. Bhattacharya, M. H. J. Bollen, J. E.Daalder, “Operation of restructured power systems”, Kluwer Academic Publishers, 2001

[7] A. J. Wood, B. F. Wollenberg, “Power generation, operation & control”, J. Wiley & Sons Inc., 2005

[8] E. Hirst, B. Kirby, “Separating and measuring the regulation and load-following ancillary services”, Utilities Policy, vol. 8, Issue 2, pp. 75 – 81, June 1999

[9] E. Nobile, A. Bose, K. Tomsovic, “Bilateral market for load following ancillary services”, IEEE Trans. Power System, vol. 16, no. 4, Nov. 2001

[10] N. Jaleeli, L. S. VanSliyck, D. N.Ewart, L. H. Fink, A. G. Hoffmann, ‘Understanding automatic generation control,” IEEE Trans. Power System, vol. 7, no. 3, pp. 1106–1122, Aug. 1992.

[11] P. Kundur, Power System Stability and Control, New York: McGraw-Hill, 1994.
[12] S. Corsi, P. Marannino, N. Losignore, G. Moreschini, G. Piccini, "Coordination between the reactive power scheduling function and the hierarchical voltage control of the EHV ENEL system," IEEE Trans. Power Syst., vol. 10, no. 2, pp. 686–694, May 1995.
[13] UCTE Operation Handbook, v 2.5E, UCTE, July 20, 2004. Available: http://www.ucte.org
[14] VDN, Germany, Transmission Code: Network and System Rules of the German Transmission System Operators, Aug. 2003. Available: http://www.vdn-berlin.de
[15] NEMMCO, Australia, Market Ancillary Service Specification, No1.5, Final, Feb. 27, 2004.Available:http://www.nemmco.com.au
[16] E. Nobile, A. Bose, "An area-wise voltagecontrol scheme suitable for setting up a VAr ancillary market", International Conference on Power System Technology, Vol. 2, pp. 1948-1953, Nov. 2004
[17] P. Lagonotte, J. C. Sabonnadiere, J. Y. Leost, J. P. Paul, "Structural analysis of the electrical system: Application to secondary voltage control in France," IEEE Trans. Power Syst., vol. 4, pp. 479–486, May 1989.
[18] K. Bhattacharya, J. Zhong, "Reactive power as an ancillary service", IEEE Trans. Power Syst., vol. 16, pp. 294–300, May 2001