# WECC AUTO TIME ERROR CORRECTION ANALYSIS

Prepared for

**The NAESB Inadvertent Interchange Payback Task Force**

by

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**December 1, 2003**

## 1. INTRODUCTION

The WECC Auto Time Error Correction Methodology was presented to the NAESB Inadvertent Interchange Payback Task Force at the September 15, 2003 meeting. One of the premises upon which the methodology is based is that equity in joint Inadvertent Interchange payback and time error correction can only be achieved through the payback of Primary Inadvertent Interchange. This premise that there is only one way available to equitably payback Inadvertent Interchange and correct time error is investigated in this paper.

## 2. INVESTIGATION METHODOLOGY

It is easier to follow examples that demonstrate the conclusions on an example interconnection than to follow the equations describing the same situation. Therefore, this paper uses an example interconnection consisting or four Control Areas (Balancing Authorities). The results of the analysis are presented as cases using this four Balancing Authority interconnection.

Since the methodologies presented do not require an extended time to demonstrate, all of the cases consist of only three consecutive hours. The first hour in all related cases is the same. Only the second and third hour of the cases differ from each other.

## 3. EXAMPLE INTERCONNECTION

For all examples, a four Balancing Authority interconnection is used. The BAs are labeled 1, 2, 3 and 4. Each BA has a unique Load Frequency Response and Governor Frequency Response for their ACE equation. These are shown in the table below. Each BA was assigned a unique demand in MWs. These are also shown in Table 1. All other values used in the simulation were calculated.

**Table 1. Balancing Authority Frequency Responses & Demand**

| BA | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Load Frequency Response | -100 MW/Hz | -200 MW/Hz | -300 MW/Hz | -400 MW/Hz |
| Governor Response | -400 MW/Hz | -800 MW/Hz | -1200 MW/Hz | -1600 MW/Hz |
| Demand | 4000 | 8000 | 12000 | 16000 |

The interconnection is shown in Figure 1. Example Interconnection.

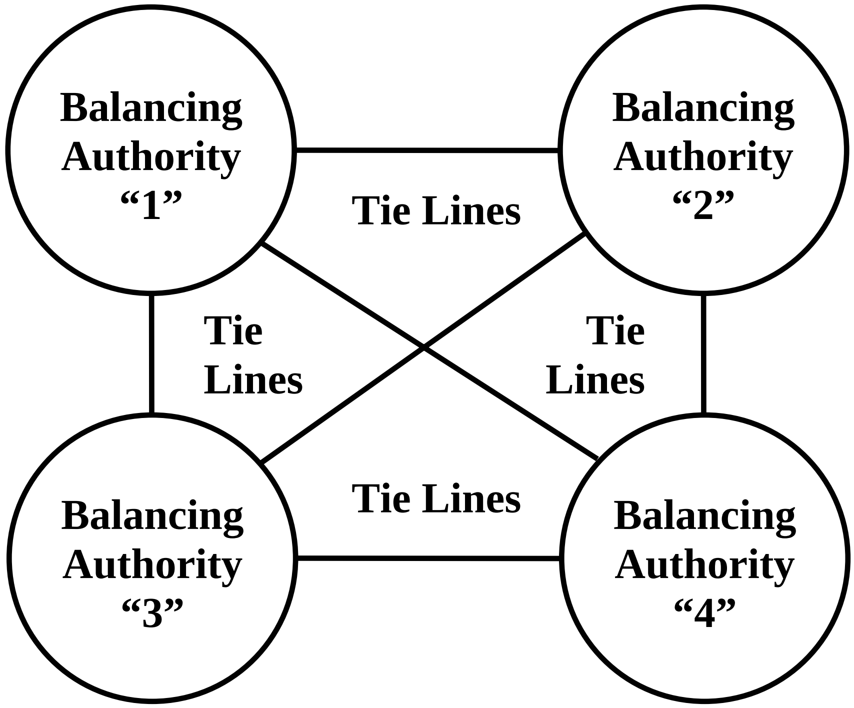


**Figure 1. Example Interconnection**

## 4. ASSUMED CONTROL ERROR

In all of the cases, it was assumed that BA 4 makes a control error of 1000 MW of over-generation in the first hour of the simulation. From that hour forward, control is assumed to be perfect for all BAs.

## 5. SPREADSHEET SIMULATION

An Excel Spreadsheet was developed to simulate the Example Interconnection. It consists of five individual sheets. The first four sheets simulate the four Balancing Authorities, and the fifth sheet simulates the interconnection. The calculated data is shown in bold; the entered data is shown as non-bold.

Each sheet is divided into three example simulations.

### Simulation 1: WECC Auto Time-Error-Correction Methodology

The first simulation presents the WECC Auto Time-Error-Correction Methodology without the spreading of payback over multiple hours.

Simulation 1 is not exactly the WECC Method, but is instead the method originally recommended by Nathan Cohn. The WECC discovered that if the Cohn method was followed with payback occurring in the next hour, the effect of large disturbances would be doubled, because, not only would the disturbance occur in the first hour, but it would reoccur in the next hour when the payback was implemented. The WECC initially limited the size of the next hour payback and extended the payback over several hours to reduce this effect. As the result of an Energy Mark report[1] on time error correction the WECC is moving toward an extended payback method based on a decay function over the week following the initial control error. The extension of the payback does not affect the conclusions drawn from the simulation examples. However, it does affect other conclusions concerning the acceptability of the methodology.

[1] Illian, H. F., Analysis of Alternative Time Error Correction, Prepared for NERC RS & RCWG, March 27, 2003.

### Simulation 2: Frequency-Offset Time-Error-Correction followed by Bilateral Inadvertent Payback

The second simulation presents the methodology used on the Eastern Interconnection. The second hour of this simulation presents frequency-offset time-error-correction. The third hour of this simulation assumes Bilateral Inadvertent Payback. It can be seen that this methodology returns the interconnection and all Balancing Authorities to exactly the same position as the first simulation at the end of the third hour. This simulation is presented before Simulation 3, to demonstrate that the time-error-correction and bilateral inadvertent payback are independent of each other and can be performed at different times without affecting the final results of the simulation. The final states after both time-error-correction and inadvertent payback have been completed are equivalent. The perceived weakness of this methodology is that it may be difficult to find a BA with opposite inadvertent to implement bilateral payback.[2]

### Simulation 3: Frequency-Offset Time-Error-Correction with Bilateral Inadvertent Payback

The third simulation presents the same methodologies as the second simulation with both the frequency offset time error correction and the bilateral Inadvertent Interchange Payback occurring in the second hour of the simulation. This simulation also returns the interconnection and all of the Balancing Authorities to exactly the same position as the first simulation. Furthermore, the third simulation results in exactly the same values for most interconnection and Balancing Authority control parameters and operating measures. In fact there are only three differences between the first and the third simulation.

## 6. DISCUSSION OF SIMULATIONS

The following discussions clarify the simulations presented.

### Simulation 1: WECC Auto Time-Error-Correction Methodology

There are still a number of problems associated with the WECC Methodology.

#### Control ACE Differs from CPS ACE:

The WECC Method requires that the ACE for control include a Primary Inadvertent Interchange Payback term; also know as an Automatic Time-Error-Correction term. Inclusion of this term in the Control ACE can result in a lower CPS1 or CPS2 performance for a BA. This comparison is shown in Columns C and D of Simulation 1. This difference occurs because the WECC Control method is inconsistent with two of the prime requirements associated with CPS1. CPS1 requires that an interconnection have only one scheduled frequency for all of its BAs at any one time. CPS1 also

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[2] **Comment by Warren McReynolds:** This is the same conclusion reached by AA Fouad, SH Kwon, in "Two-Area Analysis of System Time Error and Inadvertent Interchange Energy in Interconnected Power Systems", 85 WM 024-5. They investigated control actions necessary to implement Cohn's vector decomposition method in two ways - a two-step correction and a one-step, synchronized, correction. Both approaches ended up in the same place. But they conclude, "As shown in Eq. (33), to reduce $\varepsilon_i$ and $I_i$ to zero, the two-step correction scheme involves unnecessary regulation as compared with the synchronized, coordinated corrective control scheme." A follow-up paper included RP Schulte running simulations along the vector's 8 regions. Given your initial operating point, it identifies zones where corrective action should be terminated if a BA uses the two-step corrective control. Then they recommend the two-step corrective control...

**Response by Howard Illian:** I will go one step further. I believe that the simulation allows me to state that there is no difference between Cohn's method and the two-step method when both steps implemented simultaneously. If that is the case, additional control actions are the result of the two-step method being implemented at two different times rather than it being a result of the method itself. I would also content that at any time, a BA could choose to repay inadvertent financially without affecting the reliability of the system. Therefore, financial settlement is equivalent to immediate bilateral inadvertent payback without affecting the operating parameters of the system to make room for the payback. This is the reason why we implement energy transactions. If financial settlement is substituted for bilateral payback, the only step we need to complete the equivalent two-step payback is the time-error-correction. Since simultaneous two-step payback is equivalent to Cohn's method, then financial settlement implemented with time-error-correction is also equivalent to Cohn's method with respect to operating parameters. Unfortunately, Cohn never recognized the difference between a planned energy delivery and an unplanned energy delivery and the cost and reliability differences associated with each.

requires balanced interchange schedules between BAs, interchange schedules that sum to zero across the interconnection. The WECC Method breaks both of these rules. If the CPS ACE were to include the Automatic Time-Error-Correction term, then the technical basis, for guaranteeing the frequency error is limited to $\varepsilon_1$, would not be maintained. The CPS1 measure would then be unable to assure reliable frequency performance when all BAs meet the performance criteria.[3]

**Difference 1:** Since each BA is doing time correction independently, the interconnection does not have a single scheduled frequency. The addition of the Automatic Time-Error-Correction term essentially requires the BA to control to a different frequency than the scheduled frequency for the interconnection. Since the scheduled frequency is undefined under these conditions, the frequency error, the difference between actual and scheduled frequency is also undefined and is therefore not limited. The scheduled frequency is indeterminate.[4]

**Difference 2:** Since each BA is scheduling interchange independently, the scheduled interchange for the interconnection does not sum to zero. This failure to sum to zero changes the relationship between interconnection frequency error and sum of the BA ACE. Changing the relationship between ACE and frequency invalidates the technical basis for using zero ACE as a frequency control target. In other words, it can no longer be assumed that, if all ACE are zero, the interconnection is at scheduled frequency. As with Difference 1, the scheduled frequency is indeterminate.[5]

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[3] **Comment by Warren McReynolds:** But what is a reliable epsilon? Maybe the WECC should establish $\varepsilon_1$ based on a trial period under ATE.

**Response by Howard Illian:** I believe that you missed my point here. The math associated with CPS1 guarantees that if all BAs meet CPS1 then the frequency error for the interconnection will have a variance less than $\varepsilon_1^2$. If the rules associated with the development of CPS1 are broken, then CPS1 cannot assure any limit on frequency error. Not only is $\varepsilon_1^2$ affected, the value becomes meaningless from a technical point of view. In other words CPS1 provides no technical limit on the frequency error experienced by the interconnection. In addition, the addition of a unilateral time-error-correction term into the ACE Equation fundamentally changes the technical basis for using ACE as a control methodology. This can be easily seen by looking at the following interconnection equation.

$$-10\sum \beta_i \Delta F = \sum ACE_i$$

If a time-error-correction term is added to this equation, the relationship between ACE and interconnection frequency no longer holds and the above equality becomes the following inequality.

$$-10\sum \beta_i \Delta F \neq \sum ACE_i$$

This change not only affects the technical basis for CPS1, it also affects the relationship between ACE and frequency, and therefore, the technical basis of ACE itself.

[4] **Comment by Warren McReynolds:** Granted, once you decide to correct for any error based on unequal bias settings, each BA contribution will be weighted differently. Frequency error over time corrected for by using an integrated frequency error factor, time error, will shift the apparent scheduled frequency. Maybe we should ask if CPS is the correct performance measure. I still believe that one-sided and extended poor 1-minute performance needs incentives to meet a longer term performance measure. Hourly inadvertent is one example.

**Response by Howard Illian:** The same equations, shown in the previous comment, apply to hourly values as well as 1-minute values. If using the unilateral time-error-correction term is invalid for the 1-minute equations, then using the same equations for hourly performance also lacks validity. I have no problem with questioning CPS1. I would ask that any considered replacement be required to provide a better technical basis than that associated with CPS1. We will not improve reliability if we move back into the area of gut feel as opposed to technically justified.

[5] **Comment by Warren McReynolds:** How is this different from Eastern Interconnection unilateral payback?

**Response by Howard Illian:** Unilateral payback on the Eastern Interconnection results in a CPS1 penalty if the payback contributes to the frequency error. The unilateral payback is not required by rule. The simulation shows that all unilateral inadvertent payback that contributes to frequency error whether on the Eastern or Western Interconnection contributes to load-generation imbalance uncertainty. This would suggest that if there was a way to keep all other parameters equal and eliminate unilateral inadvertent payback, the load-generation imbalance uncertainty would be reduced and reliability would be improved. Therefore, we should consider further investigation of financial settlement because it is one way to eliminate all unilateral inadvertent payback.

**Control Actions Jointly Performed Unnecessarily:**

In the name of simplicity, the WECC unnecessarily requires the control actions for Time-Error-Correction and Inadvertent Payback to be jointly performed. This disadvantage of requiring the joint performance of these two functions is that the payback timing for both Automatic Time-Error-Correction and Inadvertent Payback must be the same.

The Energy Mark Report on Time-Error-Correction clearly demonstrated that a better way is to implement the frequency offset over an extended period with limits that are consistent with the natural variation in time-error. It was further shown that better correction would be performed over a week-long averaging period. This extended Time-Error-Correction method would also minimize the reliability impact of Time-Error-Correction.[6]

The analysis of the value of the energy component of inadvertent indicates that because of energy price volatility the best way to implement bilateral inadvertent payback would be to payback the energy as soon as possible after the inadvertent was created. This immediate bilateral inadvertent payback would minimize the difference between the value (price) of the original inadvertent and the value (price) of the payback. Requiring an extended payback period only expands the opportunities to use inadvertent and inadvertent payback value (price) differences to the financial advantage of the BA.[7] Unfortunately, discussion in the NAESB IIPTF have already demonstrated the impracticality of scheduling immediate bilateral inadvertent payback as an option to eliminate the financial advantage that might be gained from a payback-in-kind methodology. The hourly inadvertent data is simply not available on a timely enough basis to support an immediate bilateral scheduled payback-in-kind process. The alternative of using an extended averaging method to payback inadvertent in-kind assures that financial advantage can be gained anytime the hourly value (price) of energy is significantly different from the expected average value (price) over the payback averaging period. Therefore, an extended payback interval is incompatible with the charge of the IIPTF to eliminate the financial advantage that can be gained from payback-in-kind.[8]

**Simulation 2: Frequency-Offset Time-Error-Correction followed by Bilateral Inadvertent Payback**

Simulation 2 is included in the analysis to make it easier for those reviewing the simulation to see how Frequency-Offset Time-Error-Correction followed by Bilateral Inadvertent Payback returns the interconnection to the same state that the WECC Methodology does. The two steps for Simulation 2 are then combined to get Simulation 3, the simulation used for comparison to Simulation 1. There are no other conclusions drawn from Simulation 2.

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[6] **Comment by Warren McReynolds:** Those simulations are a good start. Variations on this approach should be investigated and ranked for their applicability.

**Response by Howard Illian:** I agree. The initial report purported to demonstrate that a better method could be developed. It did not state that the method offered was the optimal method.

[7] **Comment by Warren McReynolds:** Definitely, there is a trade-off here. The risk of price volatility occurring before the payback period is complete. I think theory and practice may have to compromise somewhere in between.

**Response by Howard Illian:** I suggest that the only practical way to implement immediate inadvertent payback is to settle the energy delivery financially. This eliminates all of the detrimental effects associated with paying the energy back in-kind. These include: the effects on transmission constraints, the additional losses incurred, the cost of providing regulating margin and reserves and control actions to receive the payback.

[8] **Comment by Warren McReynolds:** Again, in practice the theory still requires a compromise because all methods have a built-in time delay.

**Response by Howard Illian:** The time delay between setting the price and making the payment is significantly different from a time delay between incurring the inadvertent and paying it back in-kind. Our financial system accepts the premise that financial obligations can be settled on a net 30 basis simply because the time value of money is small as compared to the price volatility of the energy.

**Simulation 3: Frequency-Offset Time-Error-Correction with Bilateral Inadvertent Payback**

Simulation 3 was developed to demonstrate the differences between the WECC Auto Time-Error-Correction Method and Frequency-Offset Time-Error-Correction combined with Bilateral Inadvertent Payback. The first hour is exactly the same for Simulation 1 and Simulation 3. The third hour is exactly the same for Simulation 1 and Simulation 3 demonstrating that the interconnection is returned to exactly the same state using either method. In the second hour of Simulation 1 and Simulation 3 all of the actual values are the same. The only differences are shown in **Red**. These differences are discussed in the following comparison of simulations.

## 7. COMPARISON OF SIMULATIONS

There are three differences between Simulation 1 and Simulation 3. All of the differences are in the second hour of the simulation, the hour in which the payback occurs. These differences are discussed below starting at the right side of the spreadsheet.

**BA Column Q and Interconnection Column J & L – Demand at Scheduled Frequency:**

There is a difference between the Demand at Scheduled Frequency in hour two because there is a difference in the Scheduled Frequency between Simulation 1 and Simulation 3. This can be seen in Column D of the Interconnection sheet. There is no difference in the Actual Frequency, so we can conclude that the difference in these values is the result of having an indeterminate Scheduled Frequency for the interconnection in Simulation 1. This indeterminate Scheduled Frequency is one of the problems with the WECC Method that was discussed above.

**BA Columns I & M and Interconnection Column I – Generation Output Scheduled:**

Another difference between Simulation 1 and 3 is in the planning process associated with scheduling the necessary generation to meet load and control responsibilities. The simulations clearly show that the correction of the control error from hour 1 implemented in hour 2 is an unplanned process in Simulation 1 and is a planned process in Simulation 3. This difference is significant. There are three aspects to this difference. This first is the difference in control requirements between the two methods. The second is the associated with the lead time necessary to repay inadvertent with payback-in-kind. The third is the fact that the BA making the control error is in charge of both the initial error and the payback.

**Control Difference:**

In Simulation 1, BAs 1, 2 and 3 made no control errors but had to provide "regulating margin and reserves" to correct the error of BA 4 in hour 1 and then again to support the Time-Error-Correction and Unilateral Inadvertent Payback in hour 2. In other words, the "regulating margin and reserves" of the BAs that provided good control was used by the BA that had the control error for both the initial error and the payback of that error. This example highlights an additional weakness of the WECC Auto Time-Error-Correction Method. This method repays the good BA by charging that same BA a second time for its control support with a second requirement to provide additional control support as part of the repayment process.

In Simulation 3, BAs 1, 2 and 3 made no control errors and only had to provide "regulating margin and reserves" to correct the error of BA 4 in hour 1. In hour 2 the Bilateral Inadvertent Payback became part of the planned responsibility of the BAs 1, 2 and 3. This assumes that Time-Error-Correction is considered a planned responsibility. As a result, their "regulating margin and reserves" was not used in the correction process. Anyone who has worked in a control center and attempted to operate a power system recognizes that there is significant value in being able to estimate the generation requirement for the next hour. This difference between Simulation 1 and Simulation 3 is the difference in use of a BA's "regulating margin and reserves."

This unscheduled and unpaid use of one BA's "regulating margin and reserves" by another BA is the inequity that the Frequency Control Contribution is intended to correct. Even if this WECC process is continued in its current form, there is still justification for the implementation of a FCC payment associated with the control errors.

Nathan Cohn recognized the implicit effect of the FCC when he suggested that there were effectively four prices that needed to be developed for inadvertent, two for on-peak and two for off-peak. The FCC provides the technical basis for that price differentiation that Cohn suggested.

**Payback-In-Kind Difference:**

There is also some uncertainty associated with the lead time required to take full advantage of the planning for a power system. If the lead time for planning is too short, then the full benefit of planning may not be available and the "regulating margin and reserves" might still be used. On the other hand the inadvertent energy will have its supply value (price) set at the time the control error is made and it will have the value (price) of the inadvertent that is paid back using a bilateral schedule in the hour the bilateral schedule is implemented. A greater time between the initial control error and the scheduled bilateral payback results in a greater opportunity for manipulation of the inadvertent payback to achieve financial gain for the BA.

**Responsibility for Process Implementation:**

Unfortunately, the same BA that made the initial control error is also responsible for scheduling and implementing the unilateral payback-in-kind under the WECC Auto Time-Error-Correction Method. This means that the BAs with the worst control performance are the BAs that have the most influence on the implementation of the process.[9] This is a problem when it applies to a process that has no developed method of measuring performance of the BAs with respect to conformance to that process.

## 8. OTHER CONSIDERATIONS

The other alternative available is to settle the inadvertent incurred due to control errors with a financial settlement process.

**Eliminate Payback-In-Kind and Settle Financially:**

The alternative of settling inadvertent financially has three advantages.

**Replace Payback Price Timing Differences with Price Estimate Error:**

If the inadvertent is settled financially, there is no uncertainty associated with the payback-in-kind timing because the inadvertent energy does not have to be paid back. If financial settlement is used the difference between the value (price) of the energy at the time the control error is incurred and value (price) the time the payback is implemented is replace by the error in estimating the value (price) of the inadvertent in the hour the control error is incurred. As price volatility increases, the estimate error for a single hour should increase less than the difference in value between incurring inadvertent and paying it back in kind.

**Eliminate FCC Resulting from Unilateral Payback:**

In addition, if the payback-in-kind occurs unilaterally, a Frequency Control Contribution (FCC) cost is also incurred for the payback in addition to the FCC incurred for the initial control error. Therefore, financial settlement also will tend to reduce the "regulating margin and reserves" cost associated with unilateral payback-in-kind that also occurs under the payback-in-kind methodology. However, FCC will still be incurred as part of the initial control error.

**Eliminate Large Cumulative Inadvertent Accounts:**

An ongoing problem on both the Eastern and Western Interconnections has been the failure of BAs to manage their cumulative inadvertent accounts effectively. This has resulted in some large

[9] **Comment by Warren McReynolds:** As with all control performance today, there is no mandatory compliance. The poor performers are voluntarily stepping up to correct for the accumulated errors. So any method with even the slightest flaw will depend on the good graces of at least some small measure of voluntary compliance.

**Response by Howard Illian:** Hopefully, legislation will eventually make its way through congress that will make compliance mandatory.

cumulative inadvertent accounts on both interconnections. The Resources Subcommittee has been studying this problem for years without developing a solution that would fairly and effectively provide incentives for BAs to manage their cumulative inadvertent accounts and reduce the large balances that exist.

Even if the inadvertent is settled financially, the problem of time-error-correction will remain. It is only through the separation of the inadvertent settlement and the time-error-correction that both processes can be optimized.

## 9. SUMMARY AND CONCLUSIONS

There are a number of conclusions that can be drawn from these simulations. They address problems with both the WECC Auto Time-Error-Correction Method and the basic payback-in-kind methods that have been used historically on the North American interconnections.

### Conclusions on WECC Auto Time-Error-Correction Methodology:

The following conclusions apply to the WECC Method.

1. The WECC Method results in an indeterminate scheduled frequency for the interconnection which is inconsistent with the CPS1 assumptions.
2. The WECC Method results in unbalanced interchange schedules for the interconnection which is also inconsistent with the CPS1 and ACE assumptions.
3. The WECC Method unnecessarily requires the linking of time-error-correction and inadvertent payback.
4. The WECC Method results in the same *actual* system conditions as the concurrent implementation frequency-offset time-error-correction and bilateral inadvertent payback.
5. The WECC Method requires the sharing of “regulating margin and reserves” not only for the initial control errors made, but also for the unilateral inadvertent payback.[10]
6. The WECC Method increases operating uncertainty by requiring the use of unscheduled unilateral inadvertent payback instead of scheduled bilateral inadvertent payback as the primary payback method.
7. The WECC Method is incompatible with financial inadvertent settlement.
8. The BAs with the worst control performance have the greatest influence on process implementation.
9. The WECC Method has no developed controls to measure conformance to the process.

### General Conclusions from Analysis:

In addition to the conclusions that apply to the WECC Method, the following general conclusions can be drawn from this analysis.

1. Unilateral inadvertent payback results in the use of additional “regulating margin and reserves,” and demonstrates the basis for the FCC.
2. Bilateral inadvertent payback results in less operating uncertainty than unilateral payback because the payback is scheduled as part of the planning process eliminating the need for the use of additional “regulating margin and reserves” and FCC.

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[10] **Comment by Warren McReynolds:** Should be opposite sign from original regulation requirement when the secondary inadvertent is returned.

**Response by Howard Illian:** This is true, but in all cases the unilateral payback is initiated by the BA making the initial control error. This requires the BA that did not error to use its regulating and reserve margins to manage that energy on an unplanned basis for both the initial error and the payback. Even if the energy balances in the end, two wrongs to not make a right.

3. Financial settlement of inadvertent should result in less operating uncertainty than either unilateral or bilateral inadvertent payback.
4. The financial effect of inadvertent energy component for the payback-in-kind process results from the difference in value (price) of the energy when the inadvertent energy is created as compared to the value (price) of the inadvertent energy when it is paid back.
5. The financial effect of the financial settlement of the energy component results from the estimate error associated with the value (price) estimate for the energy.
6. Financial settlement will reduce the settlement error if the estimate error associated with the value (price) estimate for the energy is less than the difference in value (price) of the energy component between the inadvertent and the payback-in-kind.