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Tariff regulation to improve supply quality

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Abstract – **In electricity markets, distribution tariffs are controlled by regulatory bodies to balance interests of supply companies and energy users. Improvement of supply quality can be achieved by the adequate regulation in which distribution companies have incentives to improve the quality of supply. The paper deals with the incentive method applied in Victoria (Australia) analyzing its impact on distribution tariffs.**

Index terms **– electricity markets, distribution tariffs, quality of supply, incentives to improve supply quality.**

I. INTRODUCTION

Of many tasks when developing electricity market, the distribution tariff regulation has most significant impact on the quality of supply. The state bodies responsible for development and implementation of distribution tariffs should examine several methodologies of setting financial incentives for distribution businesses to improve quality of supply [2].

Tariff regulations, called usually “Tariff Orders” or “Tariff Rules”, are set for the defined time horizon, known as “regulation period”. The stability regulation requires to define and not to change tariff rules for a period of 5 to 7 years. In the beginning of the regulation period, a regulatory body, such as the Regulator General, defines rules, mathematical formulae and their parameters. This allows the distribution businesses to predict their financial position.

Incentives to improve supply quality should balance the costs of investment and the benefits obtained from higher standard of electricity supply. The former is easy to define and have to be compensated to distribution businesses in an electricity or network use tariff. The latter is more difficult to calculate, as cost of, for example, undelivered energy commonly defined as the Value of Lost Load varies across customer groups, hours of a day, days of a week and seasons.

The paper deals with the method used for distribution tariff regulation to create incentives to improve quality of supply. The method was applied by the Office of the Regulator-General in Victoria. The method that has been recently implemented for a regulation period 2001 – 2005 seems to be very interesting. The analysis carried out shows the impact of gaps between the quality targets and actual performance, as well as their influence on income of distribution businesses. To generalize the presented approach, some notations have been changed from the original document [1].

II. ELECTRICITY MARKET IN VICTORIA

A. Market Structure

The electricity market in Victoria was introduced in 1994 and consequently in 1997 was spread to other states creating the National Electricity Market in Australian. Currently, this market works in three geographical areas. The largest segment embraces three states: New South Wales, Victoria and South Australia. Transmission systems of this segment are connected. The Queensland electrical system is not connected with the three state markets and acts as a separate component. Similarly, the Tasmanian electricity market operates as a separate island system.

The National Electricity Market is regulated by the Electricity Market Code under National Electricity Code Administrator. Market competitiveness is verified by the Australian Competition and Consumer Committee. The state retail markets and distribution businesses operating in the state geographical areas act under regulation set by the state regulatory bodies. In Victoria, the retail market and distribution tariffs are regulated by the Office of the Regulator-General [4].

B. Tariff Regulation

The first regulation period embraced years from 1994 to 2000. It has provided the experience in regulation of distribution businesses allowing for the development of new rules for the next regulatory period 2001 – 2005. When setting up new distribution tariffs, the following issues have been taken into account:

- In the first regulatory period, positive economic trends allowed distribution businesses to obtain larger than predicted income despite the drop in electricity tariffs. This indicated a need for large a value of the X parameter in the first year of a new regulatory period.
- Verification of distribution tariffs embraces both electricity and network prices, as well as the balance between tariff components.
- Financial incentives incorporated in tariff structures to improve supply quality by tie up of tariff increase with quality targets and quality actual performance.
- Reduction of regulatory risk by setting verification rules and their parameters, such as X, Y and S for the entire regulatory period covering years 2001 – 2005.

III. TARIFF VERIFICATION

A new tariff verification methodology comprises several control formulae relating to energy tariffs, distribution network charges, and incentives to improve supply quality [1].

A. The Distribution Price Control Formula

The tariff basket distribution price control is defined as:

$$(1+CPI_t)(1-X_t)\frac{(1+S_t)}{(1+S_{t-l})} \geq \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} p_t^{ij} q_{t-2}^{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{m} p_{t-1}^{ij} q_{t-2}^{ij}} \tag{1}$$

where t defines a tariff year, i = 1, 2…n denotes a number of tariff categories for a given distribution business; j = 1, 2…m is a number of components in a tariff category „i"; p_t^{ij} is the price charged for a component „j" of tariff category „i" for tariff year „t"; p_{t-1}^{ij} is the price charged for a component „j" of tariff category „i" for tariff year „t-1"; q_{t-2}^{ij} is the quantity of component „j" of tariff „i" sold in calendar year „t-2"; CPI_t is (Consumer Price Index) defined for a particular calendar year as the CPI, as published by the Australian Bureau of Statistics (ABC) for the September Quarter immediately preceding the start of the relevant calendar year divided by the CPI, as published by the ABC for the September Quarter immediately preceding the September Quarter minus one; X_t the correction factor set for a particular regulatory period; S_t is the service adjustment to the distribution price control in calendar year "t"; S_{t-l} is the service adjustment to the distribution price control in calendar year "t-l"; l is a number of years used as a delay coefficient. In the Victorian regulation l = 6.

The values of the correction factors set for the regulatory period 2001 – 2005 are shown in Table 1.

TABLE 1

CORRECTION FACTOR X_t FOR FIVE VICTORIAN DISTRIBUTION BUSSINESSES

Distribution Business	For year 2001	For years 2002-2005
AGL Electricity Limited	0.171	0.01
CitiPower Pty	0.124	0.01
Powercor Australia Ltd	0.196	0.01
TXU Electricity Limited	0.218	0.01
United Energy Ltd	0.129	0.01

Visible differences in the correction factor X_t for year 2001 and consequent years result from the need for adjustment of higher than predicted income of distribution businesses in the first regulatory period.

The tariff basket distribution price control applies the quantity sold in year "t-2" when computing the increase or decrease in tariff values. This results from the time of submission of new tariffs when distribution businesses and the Regulator do not know the quantities sold in year "t-1". It can be said that the quantity sold in year "t-1" is a base of computing the ratio of the tariff proposed to be charged in year "t" to the tariff charged in year "t-1".

B. Rebalancing Control

Additionally to the tariff basket distribution price control, the submission should comply with the rebalancing control on each distribution tariff. This control applies from year 2002 and requires that each distribution tariff should comply with (2):

$$(1+CPI_t)(1+Y_E) \geq \frac{\sum_{j=1}^{m} p_t^{j} q_{t-2}^{j}}{\sum_{j=1}^{m} p_{t-1}^{j} q_{t-2}^{j}} \tag{2}$$

where p_t^j is the price charged for the component „j" in a particular tariff, q_{t-2}^j is the quantity of component „j" of tariff „i" sold in calendar year „t-2", the correction factor Y_E is defined for the entire regulatory period and in this case it counts for 0.2.

C. Maximum Transmission Revenue

Every distribution business should prove that its submission complies with the maximum transmission revenue control defined by (3):

$$MTR_t \geq TR_t \tag{3}$$

where TR_t is the expected revenue from transmission tariffs from all distribution customers in year „t"; MTR_t is the maximum revenue of the distribution businesses from all distribution customers in year „t" and is computed according to (4):

$$MTR_t = TC_t + G_t - D_t - K_t \tag{4}$$

where TC_t is the aggregate of all charges for connection to and use of the transmission system which the distribution business forecasts it will pay to the transmission company (VenCorp or PowerNet) during calendar year „t"; G_t is the amount the distribution business expects to pay embedded generators during calendar year „t"; D_t is the revenue which the distribution business forecasts it will earn during calendar year „t" from other distribution businesses in respect of inter-network provider distribution services tariffs net of similar charges the distribution business expects to pay other distribution businesses during calendar year "t"; K_t is a correction factor to account for any under or over recovery of actual transmission revenue in relation to the allowed transmission revenue.

E. Incentives to Improve Supply Quality

The coefficient S employed in (1) allows for the incentives to improve quality of supply. The tariff charges can be increased if a distribution businesses improves supply quality and its actual performance is better than the targets set by the Regulator. On the other hand, if a distribution business does not comply with quality levels, its tariff charges and consequently income will be reduced.

IV. QUALITY OF ELECTRICITY

A. Quality Parameters

Quality and reliability are used in various contexts. For some, quality of supply relates to voltage and current parameters if energy flows, while reliability is used to describe interruptions to supply. Most energy users understand quality of supply as a number of interruptions and their duration. Power system engineers define quality of supply setting the standards to define the appropriate levels of supply voltage and current parameters [3]. Such parameters relates to:

- Frequency of supply voltage
- Range of slow changes in supply voltage (voltage deviations)
- Fast changes in supply voltage (flickers)
- Shape of supply voltage and currents (harmonics)
- Symmetry of supply voltage and current (negative voltage component)
- In some cases, a power factor is included in parameters of supply quality

When supply quality is poor and most of the quality supply parameters are below standard levels, a customer is not directly and immediately affected. Low quality of supply affects customer's equipment after longer period when a link between quality of supply and equipment degradation is not directly visible.

B. Quality Parameters in Tariff Control

For customers more important are interruptions to supply and durations of these interruptions. For the purpose of tariff regulation three quality of supply parameters are defined. They include [1]:

- Planned minutes off supply is calculated as the sum of the duration of each planned interruption (in minutes) divided by the total number of connected distribution customers averaged over the calendar year
- Unplanned interruption frequency is calculated as the total number of unplanned distribution customers' interruptions divided by the total number of connected distribution customers averaged over the calendar year, excluding momentary interruptions less that one minute.
- Unplanned interruption duration is calculated as the total number of duration of each distribution customers' interruption (in minutes) divided by the total number of unplanned distribution customer interruptions in that year, excluding momentary interruptions less than one minute.

To set the quality targets, distribution customers are divided into three main groups:

- CBD (Central Business District) customers
- Urban customers
- Rural customers

V. COMPUTING SERVICE ADJUSTMENT

A. Service Adjustment Formula

The service adjustment that will apply in calendar year „t" is calculated as defined in (5):

$$S_t = \sum_{r,n} s_{r,n} (GAP_{t-2}^{r,n} - GAP_{t-3}^{r,n}) \quad (5)$$

where index „r" refers to three quality supply parameters, such as unplanned interruption frequency, unplanned interruption duration, and planned minutes off supply indicators; index „n" refers to the following categories of distribution customers: CBD customers, urban and rural customers; $s_{r,n}$ is the incentive rate for indicator „r" and distribution customer category „n"; $GAP_{t-2}^{r,n}$ is the performance gap for indicator "r" and distribution customers' category "n" in calendar year "t-2" and is calculated in accordance with (6); $GAP_{t-3}^{r,n}$ is the performance gap for indicator "r" and distribution customers' category "n" in calendar year "t-3" and is calculated in accordance with (7).

The performance gap for calendar year "t-2" is calculated as [1]:

$$GAP_{t-2}^{r,n} = TAR_{t-2}^{r,n} - ACT_{t-2}^{r,n} \quad (6)$$

where $TAR_{t-2}^{r,n}$ is the distribution business performance target for indicator „r" and distribution customer category „n" in calendar year "t-2", as defined by the Regulator; $ACT_{t-2}^{r,n}$ is the distribution business actual performance for indicator "r" in customer category "n" in calendar year "t-2".

The performance gap for calendar year "t-3" is set to zero if the calendar year ends on the 31st December 2003 after this year the performance gap is calculated as [1]:

$$GAP_{t-3}^{r,n} = TAR_{t-3}^{r,n} - ACT_{t-3}^{r,n} \quad (7)$$

where $TAR_{t-3}^{r,n}$ is the distribution business performance target for indicator „r" and distribution customer category „n" in calendar year "t-3", as defined by the Regulator; $ACT_{t-3}^{r,n}$ is the distribution business actual performance for indicator "r" in customer category "n" in calendar year "t-3".

TABLE 2

EXAMPLES OF QUALITY PERFORMANCE TARGETS PRESCRIBED FOR TWO VICTORIAN DISTRIBUTION BUSINESSES [1]

Distribution Business and customer category	Quality performance target	2001	2002	2003	2004	2005
Citi Power – CBD customers	Planned minutes off supply	5.9	5.9	5.9	5.9	5.9
	Unplanned interruption frequency	0.25	0.25	0.25	0.25	0.25
	Unplanned interruption duration	63	63	63	63	63
AGL Electricity	Planned minutes off supply	6	6	6	6	6

Electricity – Urban customers	Unplanned interruption frequency	1.42	1.36	1.32	1.30	1.27
	Unplanned interruption duration	60	59	59	58	58
AGL Electricity – Rural customers	Planned minutes off supply	14	14	14	14	14
	Unplanned interruption frequency	2.38	2.38	2.25	2.25	2.25
	Unplanned interruption duration	51	51	50	50	50

B. Performance Targets

The prescribed performance targets depend on customer categories and a distribution businesses geographical area. Setting the performance target, the Regulator has to take into account the actual level of supply quality and predicted cost to achieve the target set. It should be balance between quality targets and the increase in customer tariff to improve supply quality. Table 2 shows the quality targets defined for the Victorian distribution businesses. They can be, to some degree, indicators how to define quality target; however, if such a method is to be implemented in other countries, local conditions of distribution network should be carefully taken into consideration. If some customers require very high supply quality, they can enter into various quality contracts with distribution businesses additionally to the quality targets defined by the regulatory body.

C. Incentive Rates

Values of incentive rates should be defined for each customer group in a particular distribution business and three main supply parameters for which the performance targets have been defined. Table 3 shows examples of incentive rates for two distribution businesses.

TABLE 3

EXAMPLES OF INCENTIVE RATES FOR TWO VICTORIAN DISTRIBUTION BUSINESSES

Distribution business	Parameter	Measure of parameters	CBD customers	Urban customers
CitiPower Pty	Unplanned interruption frequency	%/0.01 interruptions	0.0268	0.0318
	Unplanned interruption duration	%/minute	0.0068	0.0333
	Planned minutes off supply	%/minute	0.0105	0.0135
Distribution business	**Parameter**	**Measure of parameters**	**Urban customers**	**Rural customers**
AGL Electricity	Unplanned interruption frequency	%/0.01 interruptions	0.0236	0.0013
	Unplanned interruption duration	%/minute	0.0364	0.0040
	Planned minutes off supply	%/minute	0.0099	0.0006

D. Capital Cost in Distribution Tariffs

The tariff regulation in Australia allows the return from investment in regulated businesses. This is achieved by the inclusion in the company cost the value of WACC. The WACC values are defined by the regulatory body for a particular regulatory period. In the first regulatory period, comprising years 1995-2000, the pre-tax WACC was equal to 11.9% to attract investors during privatization. In the second regulatory period (2001–2005), the predicted economy conditions allowed to reduce the pre-tax value of WACC – Table 4.

TABLE 4

EXAMPLES OF PRE-TAX WACC VALUES FOR THE VICTORIAN DISTRIBUTION BUSINESSES [1]

Distribution Business	Pre-tax WACC in year 2001- 2005
AGL Electricity Limited	6.9%
CitiPower Pty	6.8%
Powercor Australia Ltd	7.2%
TXU Electricity Limited	6.9%
United Energy Ltd	7.1%

VI. SIMULATION

To examine the methodology and its impact on distribution tariffs, several cases have been simulated for the parameters of similar values. It is worth emphasis that simulation does not aim at the analysis of particular quality parameters for the Victorian distribution businesses and an impact of quality performance on distribution tariffs. The analysis shows the general features of such a method which can be considered as a way of quality regulation in other countries.

One of the most important problems is an impact of the transition period on the quality adjustment, and consequently on distribution tariffs. To examine the impact of the initial transition period, two cases have been simulated. The first one assumes that a distribution business reaches quality target in 2005, i.e. two years after the quality adjustment was applied.

The second case simulated assumes that the quality targets will be achieved in the first year of the adjustment application, i.e. in 2003. To draw general conclusions, differences between quality targets and actual performance were calculated in percentage of the targets defined.

A. Case A – Achieving Performance Target in 2005

Actual performance and quality targets for three characteristic parameters are presented in tables below. A distribution business improves gradually supply quality, reaching the quality target in 2005. Before this year, its quality of supply was poor counting 1% deviation for the 2005 target in each year. After year 2005, the company still improves quality of supply by 1% per year from the 2005 target.

TABLE 5

PLANNED MINUTES OFF SUPPLY

Year	Actual	Target	S_t	$S_{(t-6)}$
1997	6.37			
1998	6.31			
1999	6.25			
2000	6.20			
2001	6.14	5.9		
2002	6.08	5.9		
2003	6.02	5.9	-0.0025	
2004	5.96	5.9	0.0006	
2005	5.90	5.9	0.0006	
2006	5.84	5.9	0.0006	
2007	5.78	5.9	0.0006	
2008	5.72	5.9	0.0006	
2009	5.66	5.9	0.0006	-0.0025
2010	5.61	5.9	0.0006	0.0006

The data in tables show the negative values of S_t in the first year of quality adjustment. This results from the way how S_t is calculated. It is computed as a difference between gap performance defined by (8) and (9). In tariff submission for year 2003, quality adjustment S_t is calculated for year 2001 when the actual performance is smaller than the target assumed, so the value of $GAP_{t-2}^{r,n}$ (for year 2001) is negative. For this year the value of $GAP_{t-3}^{r,n}$ is zero, as this component is calculated according to (9) for the tariff submission after 2003.

In the tariff submission for 2004, the quality adjustment S_t becomes positive despite that in year "t-2" for this submission, i.e. year 2002, still the actual performance is smaller than the assumed target. However, in the submission 2004, coefficient $GAP_{t-3}^{r,n}$ is computed and being smaller than zero changes the value of S_t to positive. Such value allows the increase of distribution tariffs in year 2004 – see Table 8.

TABLE 6

UNPLANNED INTERRUPTION FREQUENCY

Year	Actual	Target	S_t	$S_{(t-6)}$_
1997	0.270			
1998	0.268			
1999	0.265			
2000	0.263			
2001	0.260	0.25		
2002	0.258	0.25		
2003	0.255	0.25	-0.0003	
2004	0.253	0.25	0.0001	
2005	0.250	0.25	0.0001	
2006	0.248	0.25	0.0001	
2007	0.245	0.25	0.0001	
2008	0.243	0.25	0.0001	
2009	0.240	0.25	0.0001	-0.0003
2010	0.238	0.25	0.0001	0.0001

TABLE 7

UNPLANNED INTERRUPTION DURIATION

Year	Actual	Target	S_t	$S_{(t-6)}$_
1997	68.040			
1998	67.410			
1999	66.780			
2000	66.150			
2001	65.520	63		
2002	64.890	63		
2003	64.260	63	-0.0171	
2004	63.630	63	0.0043	
2005	63.00	63	0.0043	
2006	62.370	63	0.0043	
2007	61.740	63	0.0043	
2008	61.110	63	0.0043	
2009	60.480	63	0.0043	-0.0171
2010	59.850	63	0.0043	0.0043

However, the negative value of S_t, which appeared in year 2003, is transformed six years later into negative value of S_{t-6} in year 2009. This allows for the larger tariff increase in 2009. However, in the next year increase of distribution is significantly smaller – Fig. 1.

The analysis of components of quality adjustment S_t shows the largest share of parameters relating to unplanned interruption duration, while unplanned interruption frequency influence on quality adjustment is not significant – Fig. 2. This indicates that parameters in $s_{r,n}$ should be selected in A different way to allow the more uniform impact of all quality supply parameters.

TABLE 8

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QUALITY ADJUSTMENT VALUES

Year	$S_t = S_{t1} + S_{t2} + S_{t3}$	$S_{(t-6)} = S_{(t-6)\_1} + S_{(t-6)\_2} + S_{(t-6)\_3}$	$(1+S_t)/(1+S_{(t-6)})$
1997			
1998			
1999			
2000			
2001			
2002			
2003	-0.0199		0.9801
2004	0.0050		1.0050
2005	0.0050		1.0050
2006	0.0050		1.0050
2007	0.0050		1.0050
2008	0.0050		1.0050
2009	0.0050	-0.0199	1.0254
2010	0.0050	0.0050	1.0000

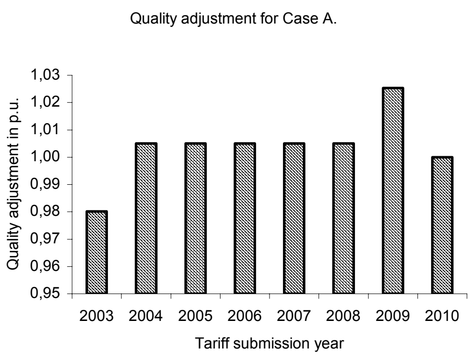

Fig. 1. Quality adjustment for Case A

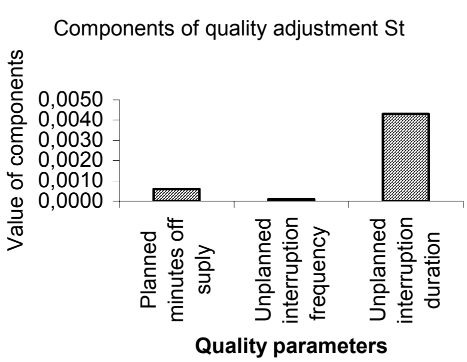

Fig. 2. Components of quality adjustment

B. Case B – Achieving performance target before 2003

In the second simulated case, it was assumed that a distribution company was able to achieve the quality target in year 2002, i.e. the one year before the application of quality adjustment. After year 2002, the company improves supply quality with actual performance rate 1% per year. This should allow the adjustment of distribution tariffs up due to better performance. However, the coincidence of parameters S_t and S_{t-6} results in non uniform increase of distribution tariffs. - Table 9 and Fig. 3.

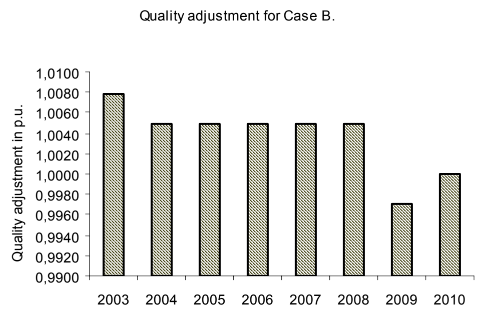

Fig. 3. Quality adjustment for Case B

TABLE 9

QUALITY ADJUSTEMENT PARAMETERS FOR CASE B

Year	$S_t = S_{t1} + S_{t2} + S_{t3}$	$S_{(t-6)} = S_{(t-6)\_1} + S_{(t-6)\_2} + S_{(t-6)\_3}$	$(1+S_t)/(1+S_{(t-6)})$
1997			
1998			
1999			
2000			
2001			
2002			
2003	0.0078		1.0078
2004	0.0049		1.0049
2005	0.0049		1.0049
2006	0.0049		1.0049
2007	0.0049		1.0049
2008	0.0049		1.0049
2009	0.0049	0.0078	0.9971
2010	0.0049	0.0049	1.0000

VII. CONCLUSIONS

The method examine allows for the incentive to improve supply quality in distribution networks when tariffs are controlled by the regulatory body. However, in transition period incentive are not directly tied up with quality improvement. More research should be carried out on tariff incentive to improve supply quality.

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VIII. BIOGRAPHIES

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