PROBABILITY OF ISLANDING IN UTILITY NETWORK DUE TO GRID CONNECTED PHOTOVOLTAIC POWER SYSTEMS

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Main Conclusion

Probability of encountering an islanding is virtually zero

Let me prove you why

Introduction (1)

- Islanding is not allowed as the power quality for loads in the island cannot be guaranteed and where safety of maintenance crews is not assured

- International discussions
  - Big Problem versus No Problem
  - High-end Protections versus Simple Protections
  - ‘Personal feeling’ and ‘Intuition’ make the discussions extremely difficult

- Information on probability and risk of islanding is not available

Introduction (2)

- In 1999 the Netherlands started a research project to determine the probability of islanding in a low voltage power network based on measurements of loads and the power produced by a PV system
- Research is integrated in the Task V workplan and other international research programs
- Work was funded by EnergieNed, Novem and KEMA

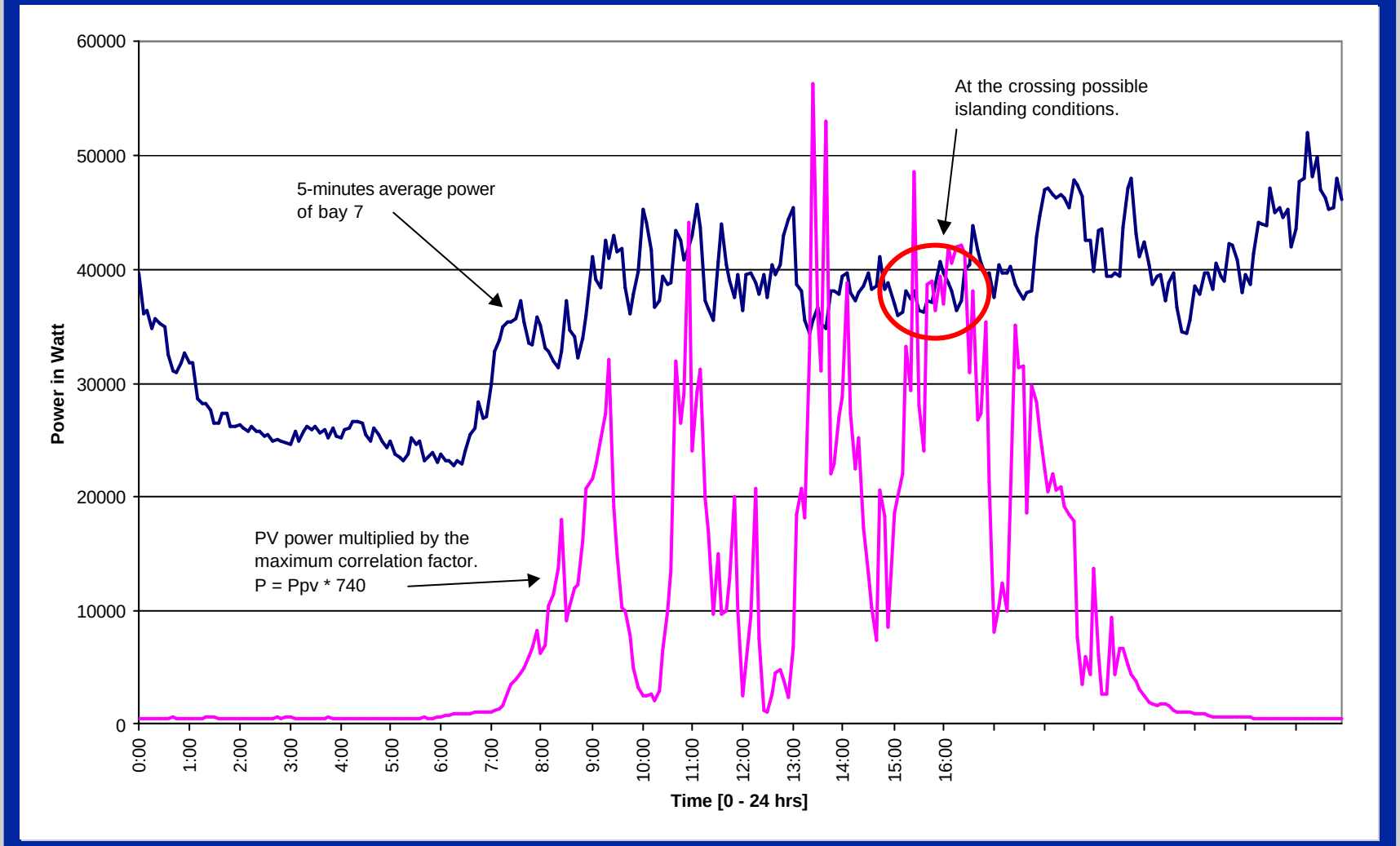
Methodology (1)

- Residential area with high penetration level of PV systems is not available
- Alternative method was developed to measure the load of a distribution transformer and all outgoing bays plus the power produced by a PV-system
- Measuring system must ‘capture’ islanding thus, data samples of load and PV power are taken every second for one year to include seasonal variations

Methodology (2)

- PV power is measured using a 100 Wp system
- Direct comparison with the load of the network is therefore not possible
- PV power must be multiplied by a constant factor before comparison can be made
- What constant factor should we use?
  - Look at the available roof surface in the residential area, or
  - Determine from the measured data the ratio between load and PV power and look for the ratio that occurs most frequently

Methodology (3)



Methodology (4)

- Various penetration levels of PV systems can be evaluated when using different constant factors for the multiplication of the PV power
- Comparison can be made for active power
  - for indication only
- Combination of active and reactive power
  - The real situation!

Residential Area (1)

Residential area is located in ‘Rijkerswoerd’ a suburb south of Arnhem

Residential Area (2)

Area is representative as a modern housing estate, approximately 7 years old

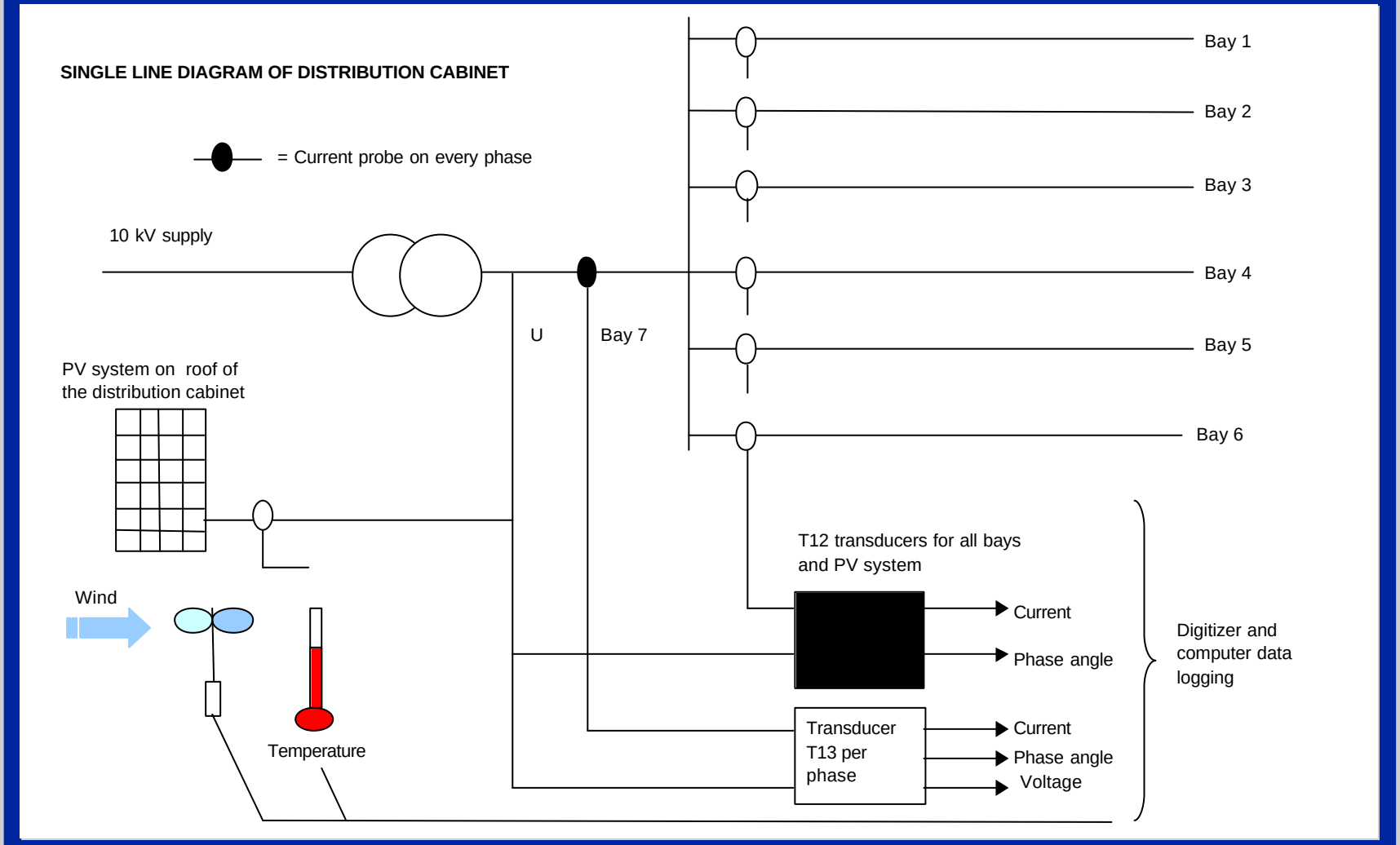
Residential Area (3)

Distribution transformer 10 kV / 230 V

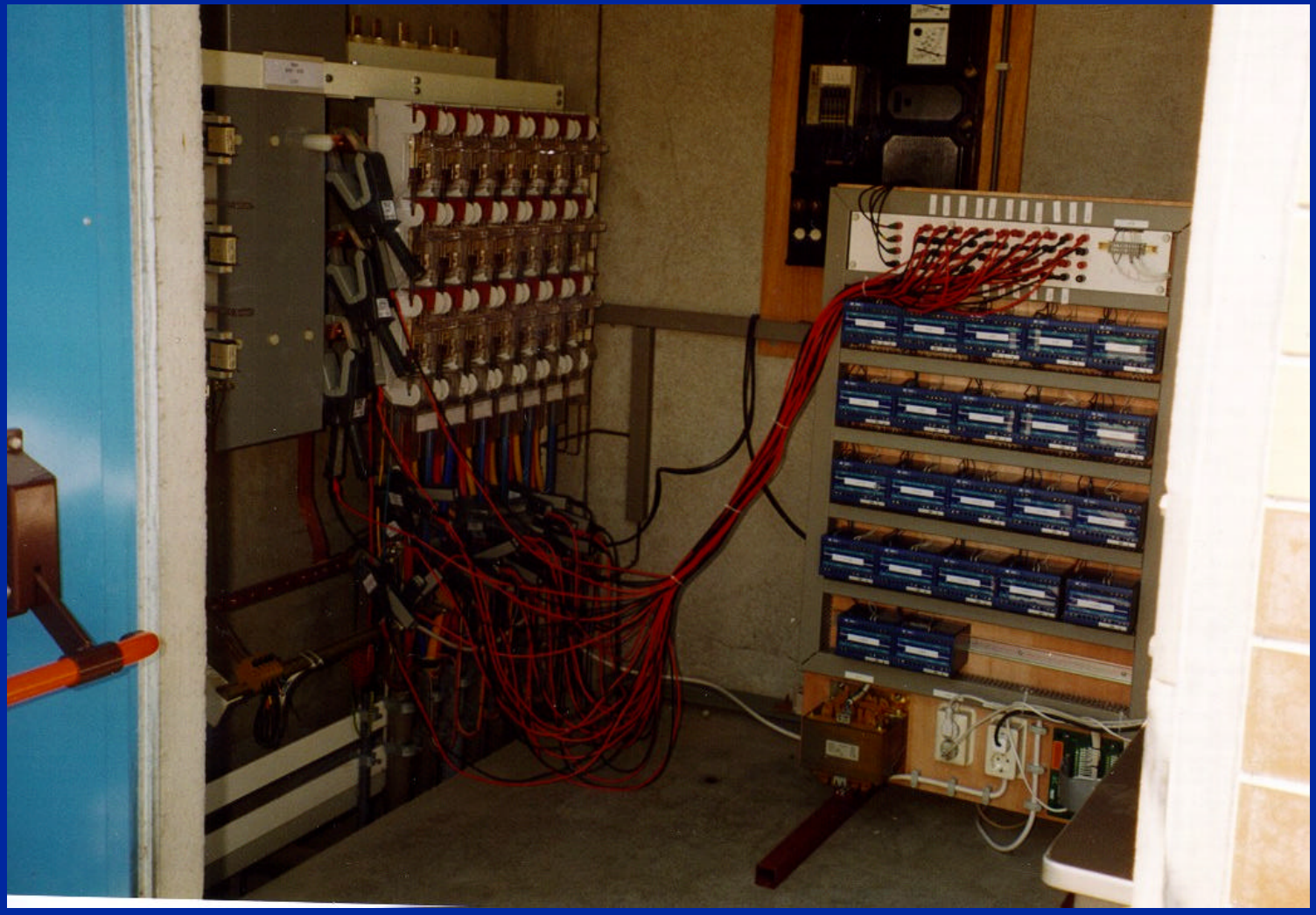
Bay	
1	Pub. lighting
2	7 houses
3	50 houses
4	78 houses
5	55 houses
6	56 houses
7	246 houses

Distribution cabinet of NUON

Test Setup and Measuring System (1)



Test Setup and Measuring System (2)



Test Setup and Measuring System (3)

Test Setup and Measuring System (4)

- Measured and logged parameters
  - Red, Yellow and Blue phase voltage
  - Red, Yellow and Blue phase current per bay
  - Red, Yellow and Blue phase angle per bay
  - PV current and phase angle
  - Speed of wind
  - Temperature
- 750 MB of data per month = 9 GB per year
- Measuring period from May - 1999 to April 2000

Determination of Ratio PV and Load (1)

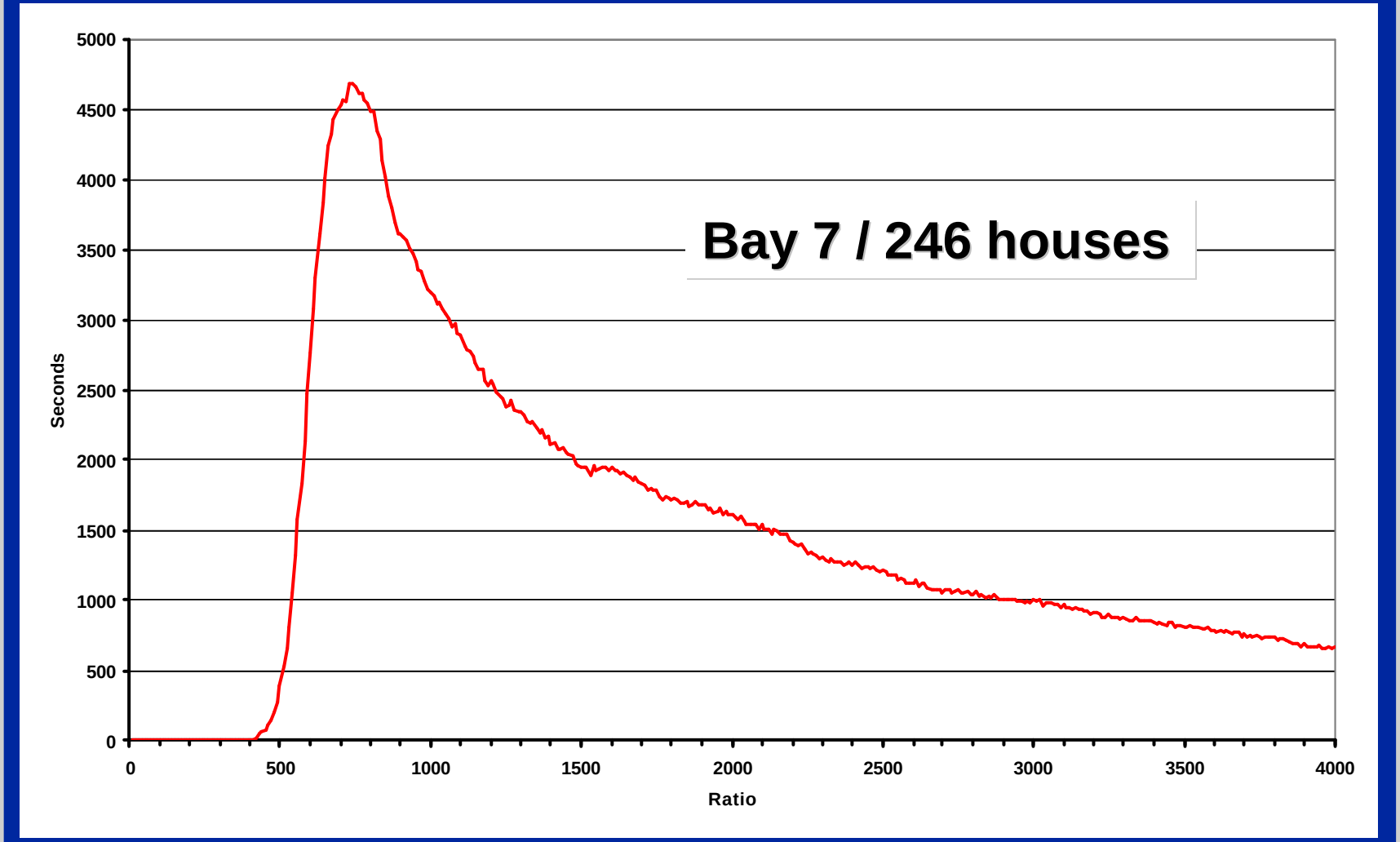
- We must determine a reasonable factor for the multiplication of the PV power before the comparison between load and PV power can be made

- Calculate ratio for every second in whole year

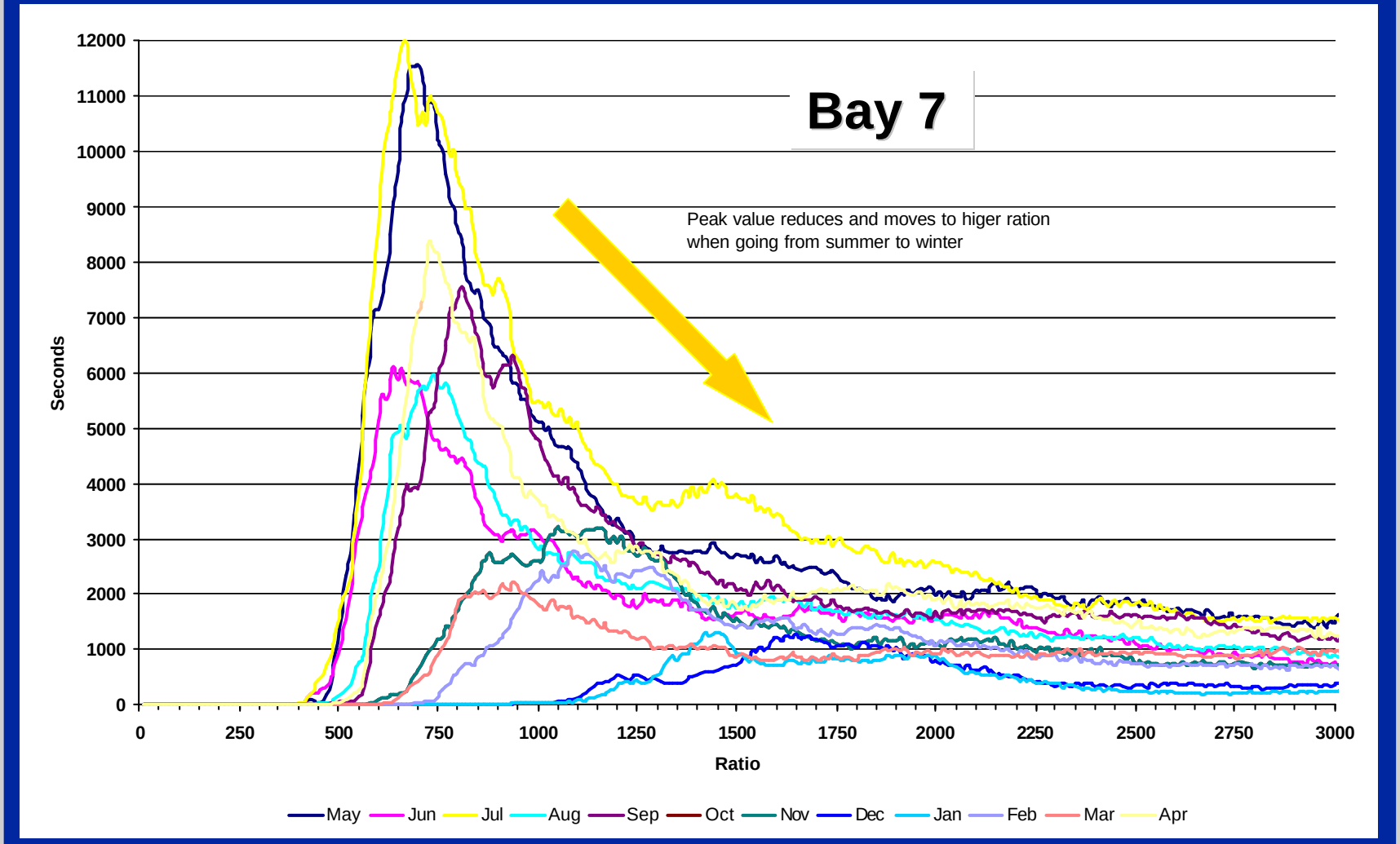
$$\text{Ratio} = \frac{P_{load}}{P_{pv}} \qquad (\text{for } P_{pv} > 0)$$

- Plot ratio in frequency distribution chart for the whole year

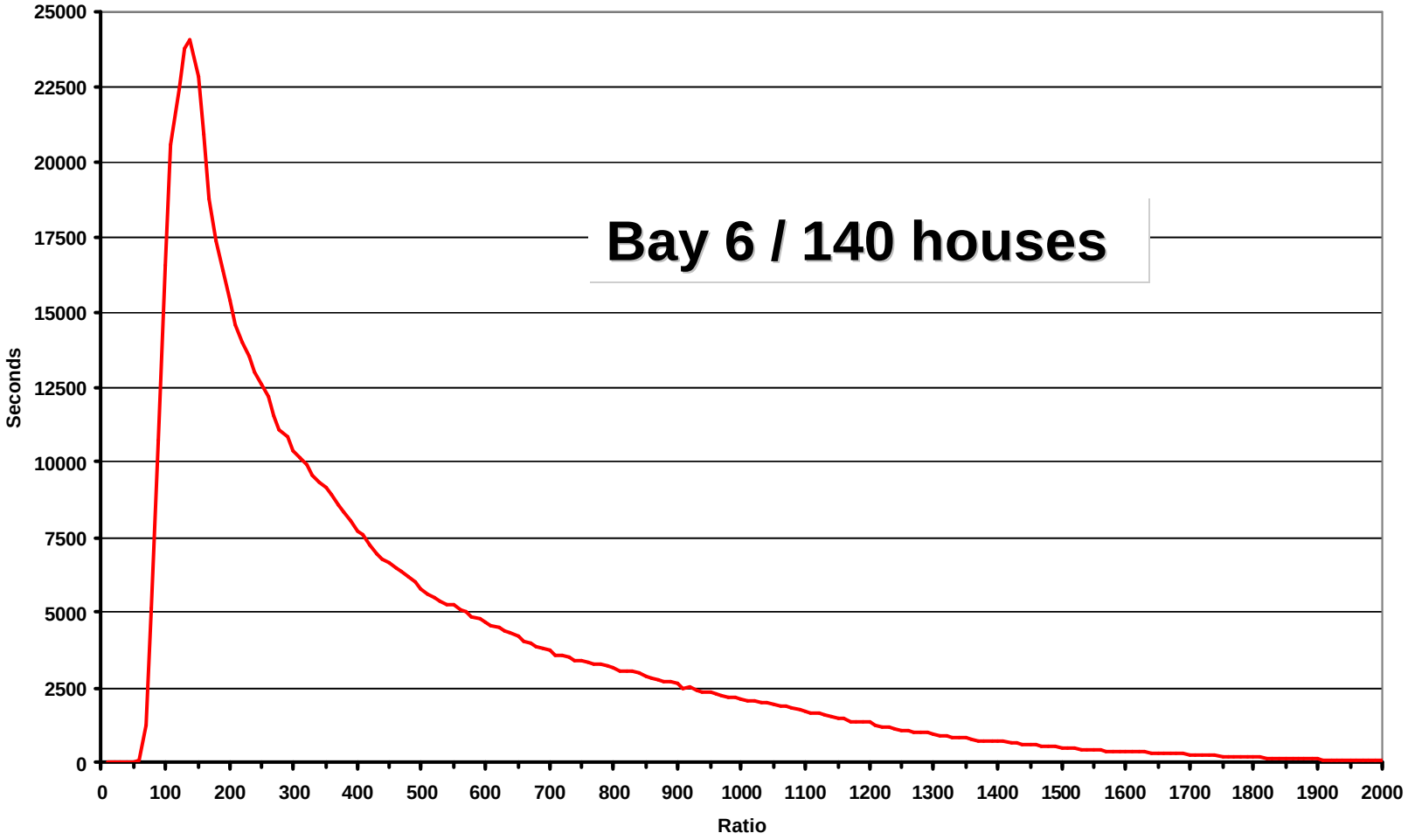
Determination of Ratio PV and Load (2)



Determination of Ratio PV and Load (3)



Determination of Ratio PV and Load (4)

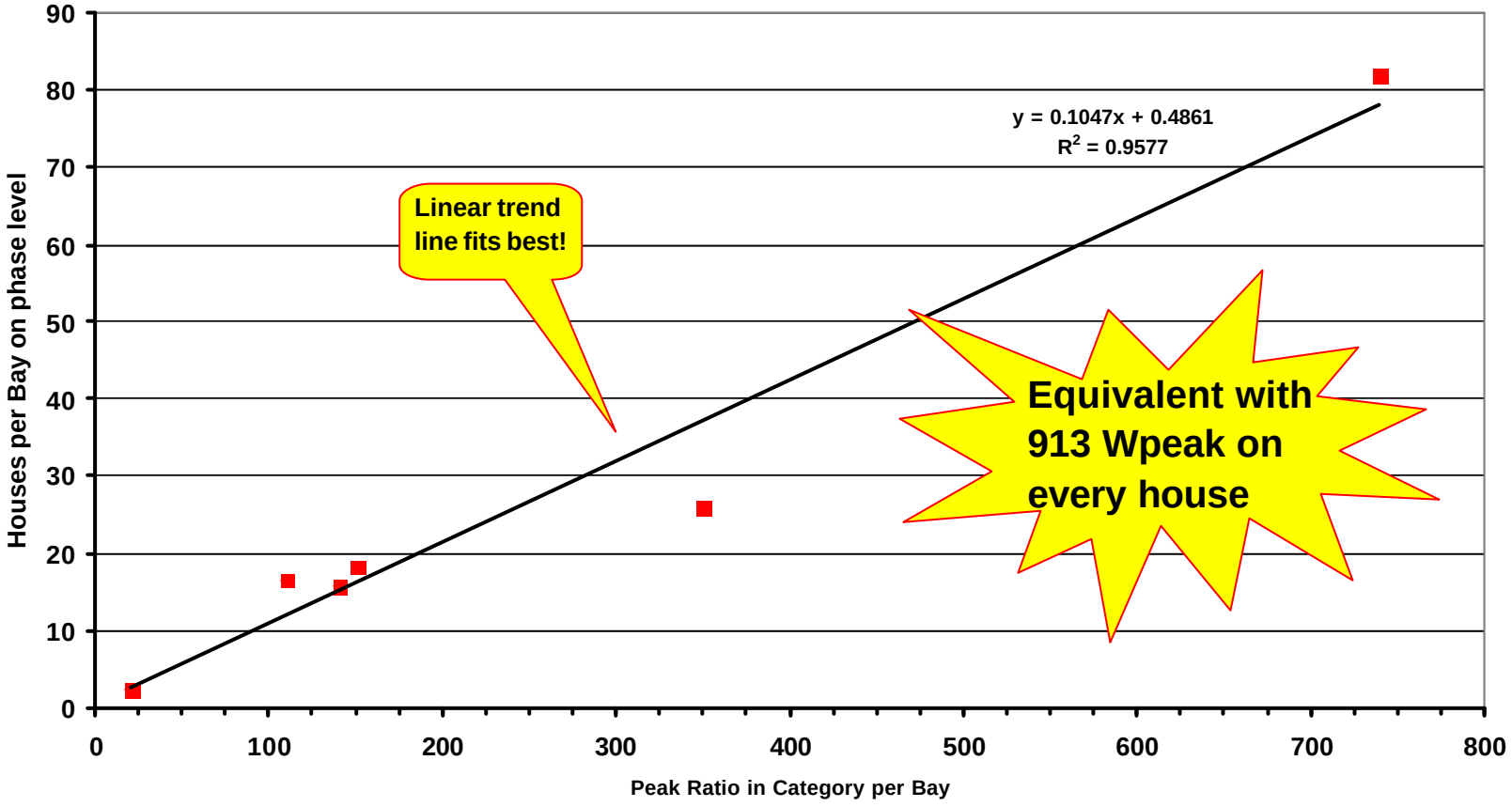


Determination of Ratio PV and Load (5)

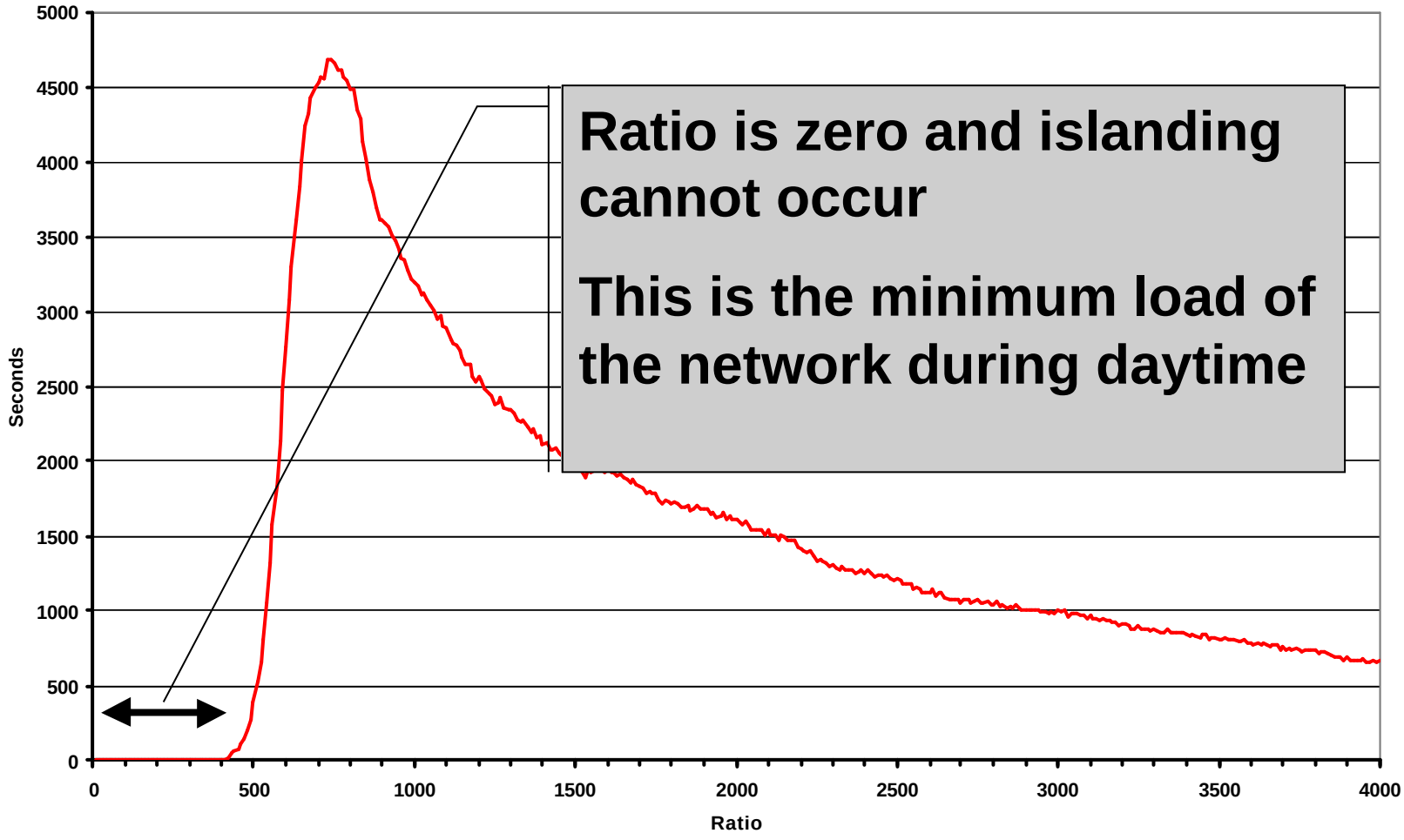
Peak value of ratio for the different bays

Bay	Peak value at ratio	Houses to bay
Bay 2	20	7
Bay 3	110	50
Bay 4	350	78
Bay 5	150	55
Bay 6	140	56
Bay 7	740	246

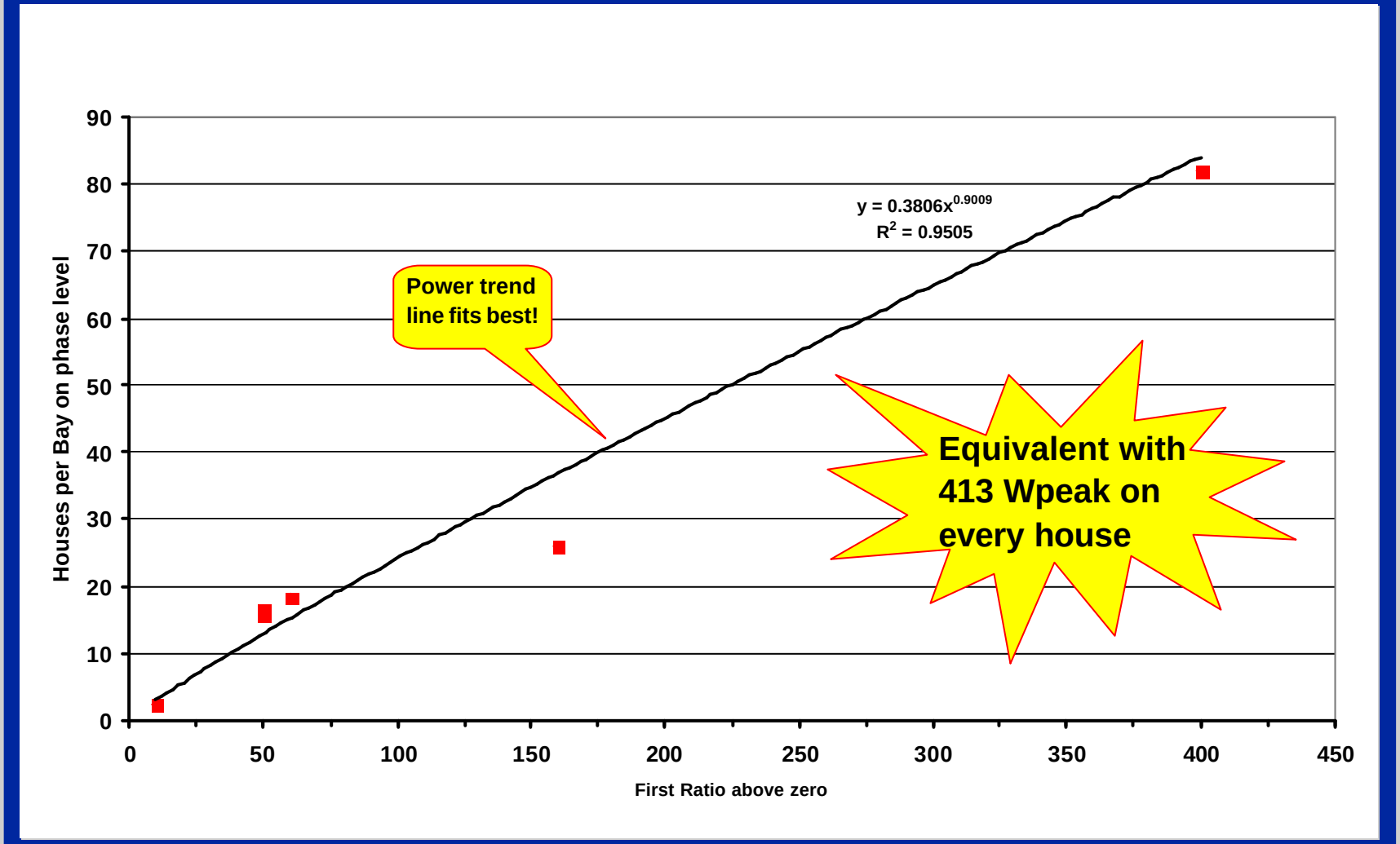
Determination of Ratio PV and Load (6)



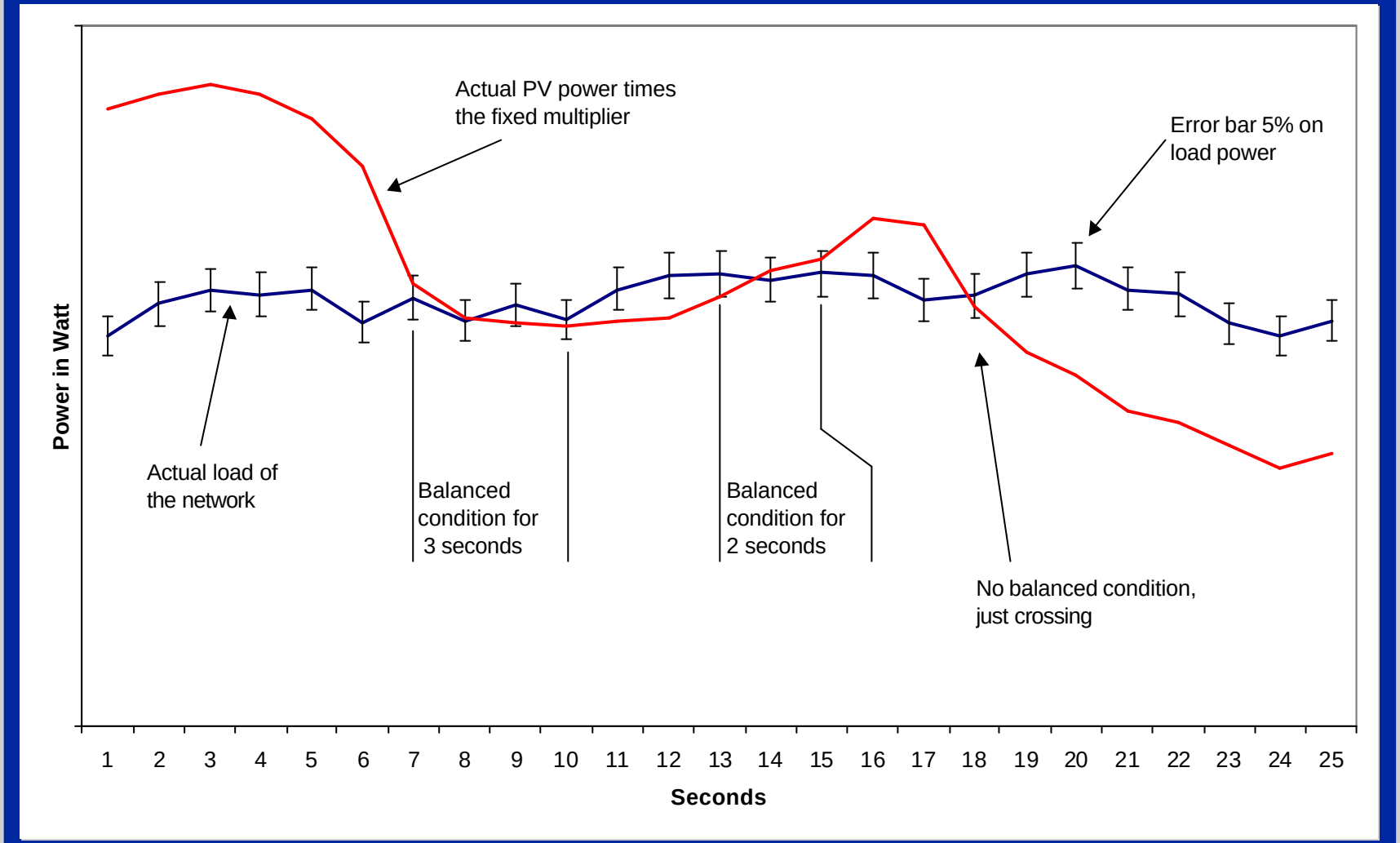
Determination of Ratio PV and Load (7)



Determination of Ratio PV and Load (8)



Method to determine balanced conditions (1)

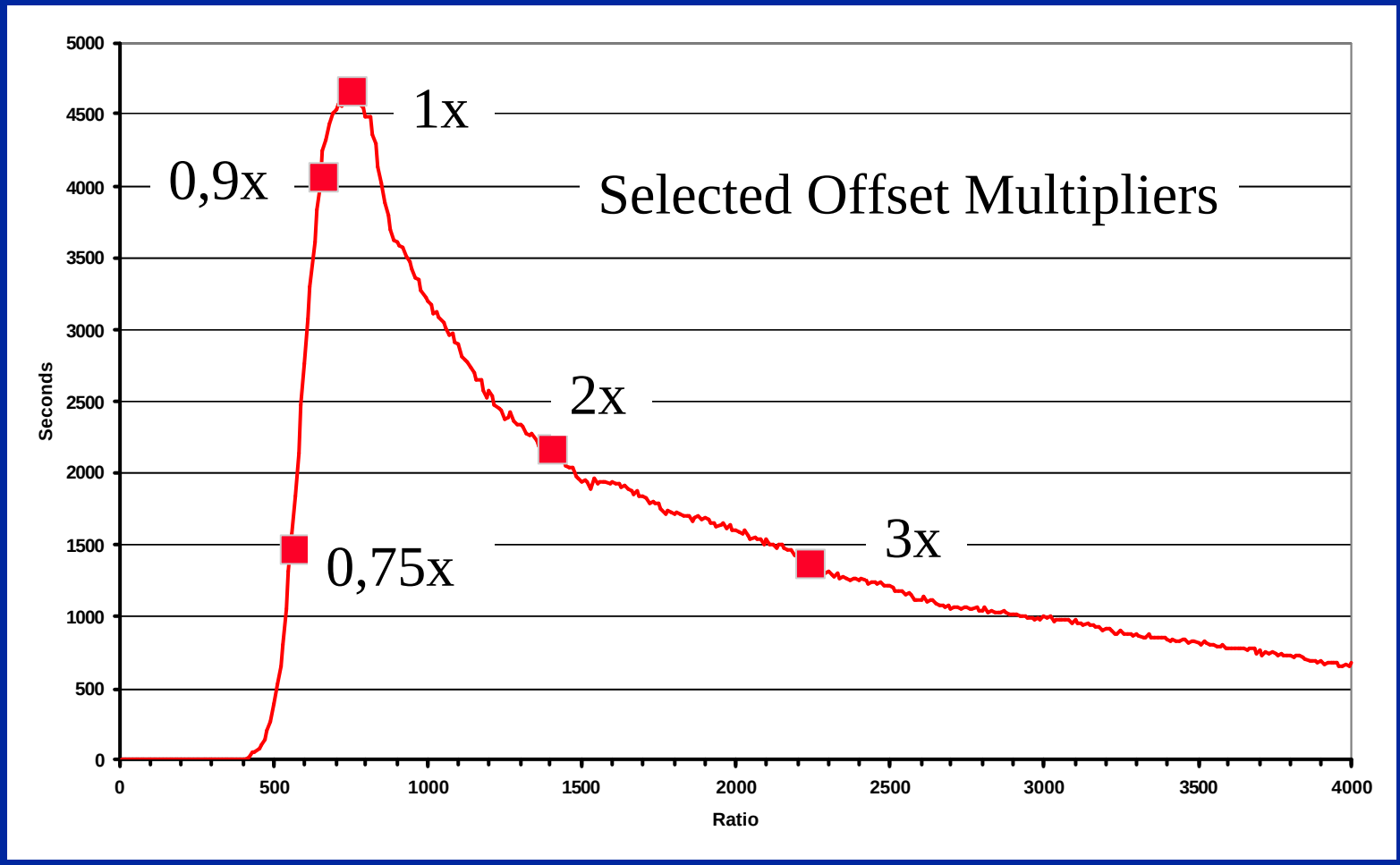


Method to determine balanced conditions (2)

For the comparison we have two variables:

- Multiplier of the PV power to vary the penetration level of the PV systems
  - Base is at the peak of the ratio times an offset to simulate lower and higher penetration levels
- Error margin for accepting balanced conditions
  - This error margin is used to simulate the mismatch of active power and reactive power that may be present in an island for which the islanding remains stable

Method to determine balanced conditions (3)



Method to determine balanced conditions (4)

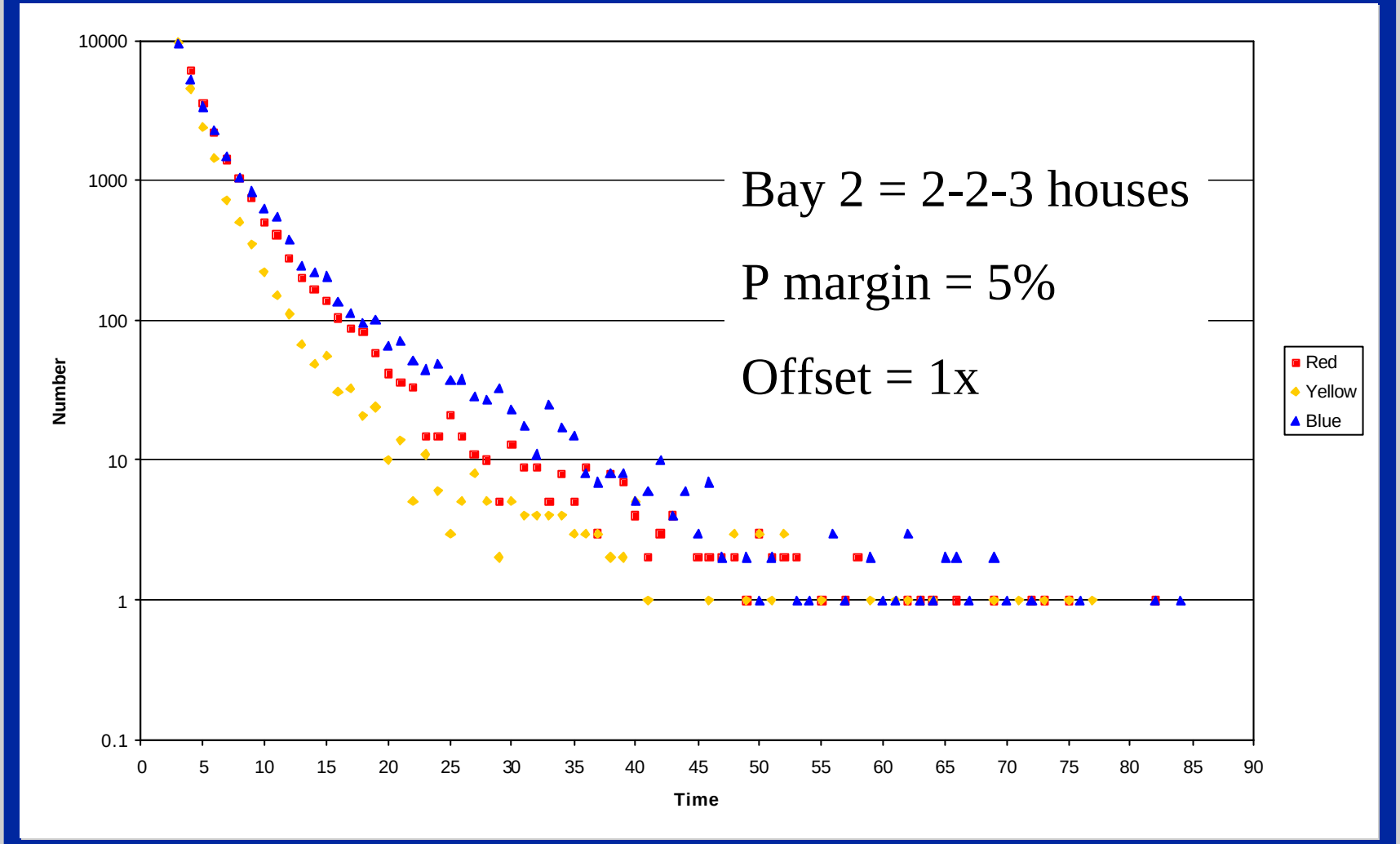
Bay	.75x	.9x	1x	2x	3x
2	15	18	20	40	60
3	147	99	110	220	330
4	263	315	350	700	1050
5	113	135	150	300	450
6	105	126	140	280	420
7	555	666	740	1480	2220

- Analyses are made for every bay separately

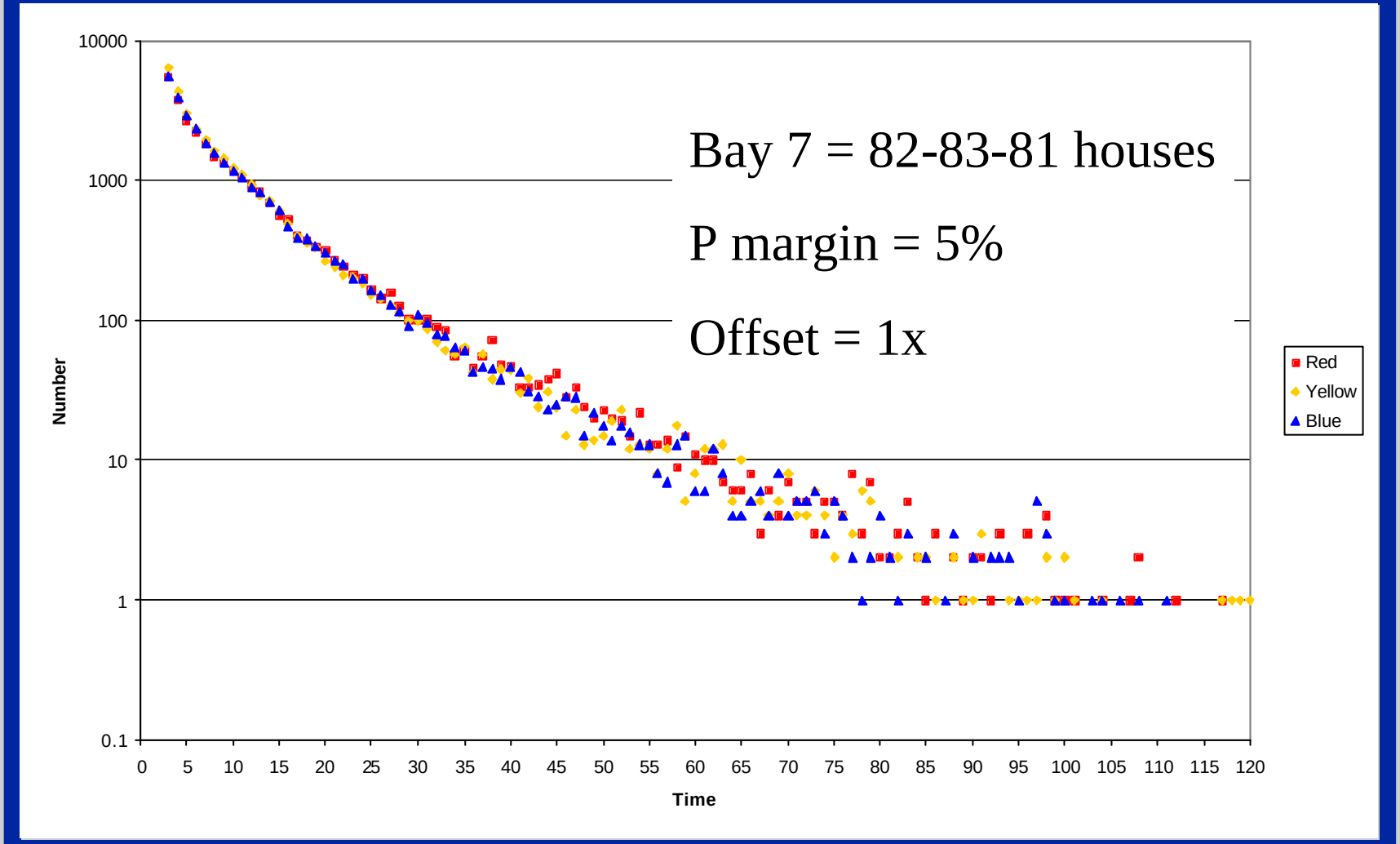
Method to determine balanced conditions (5)

	P = ±2% Q = ±2%	P = ±5% Q = ±2%	P = ±10% Q = ±5%	P = ±15% Q = ±10%
Mult. = 0.75x	v	v	v	v
Mult. = 0.9x	v	v	v	v
Mult. = 1x	v	v	v	v
Mult. = 2x	v	v	v	v
Mult. = 3x	v	v	v	v

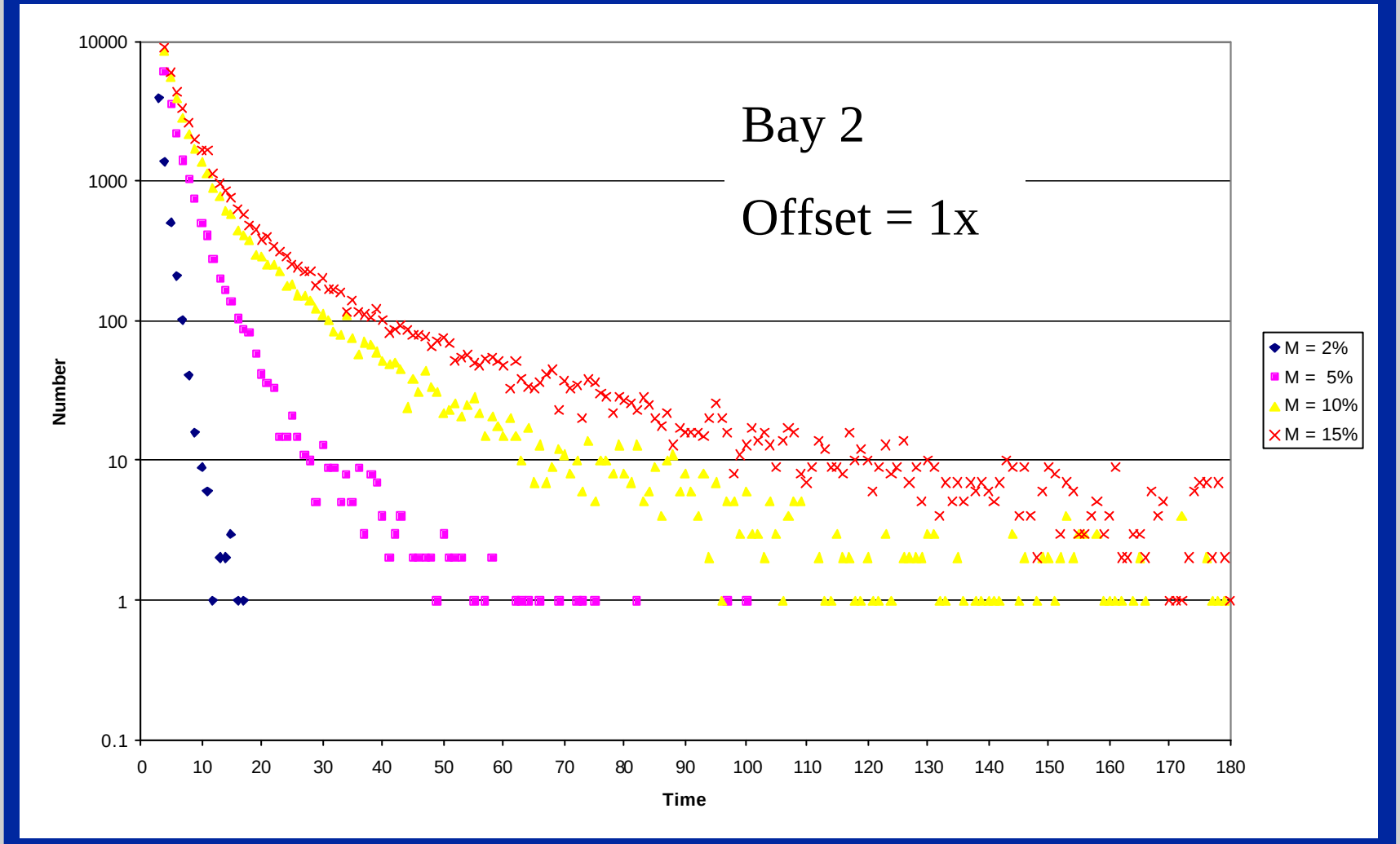
Balanced conditions for active power (1)



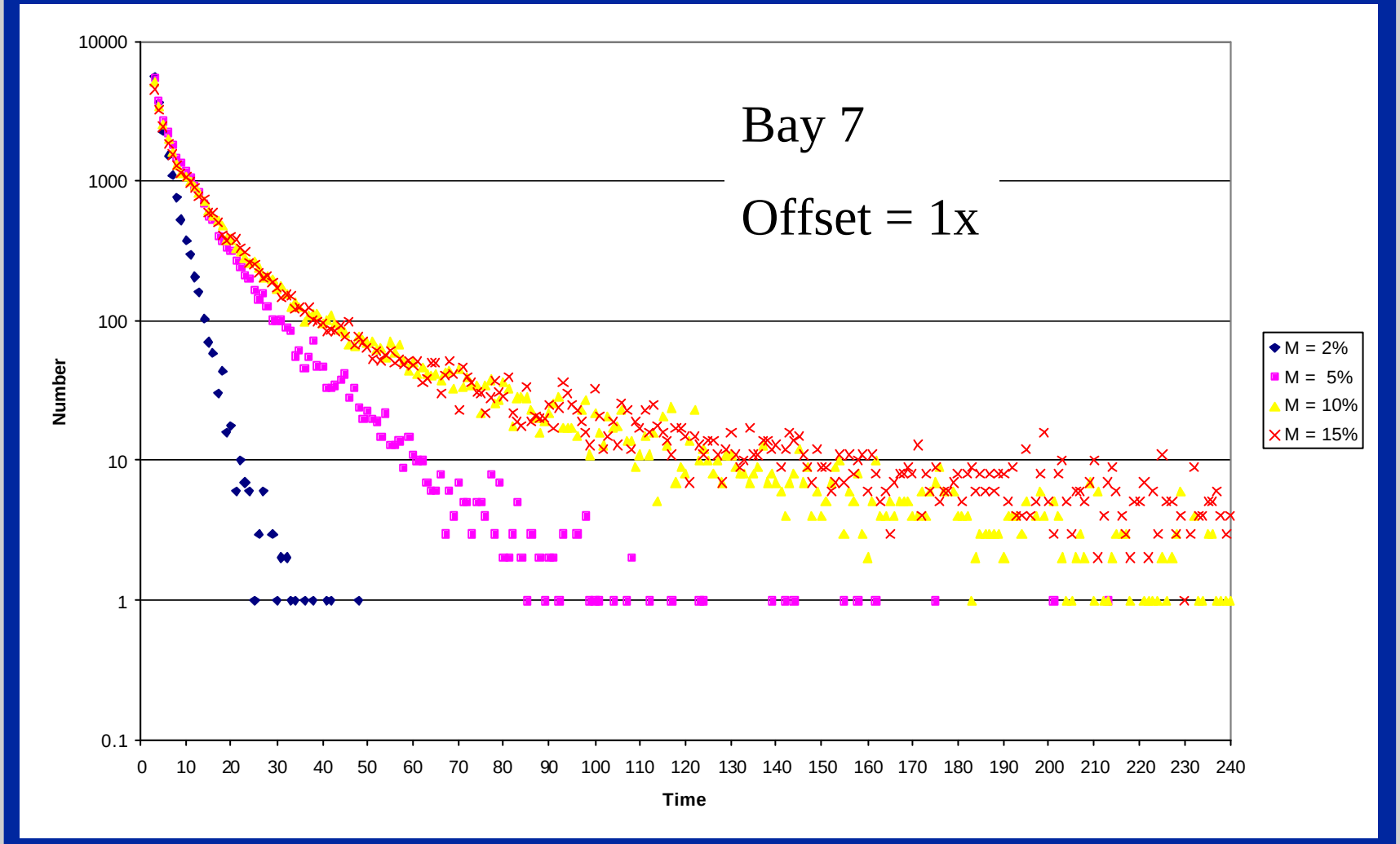
Balanced conditions for active power (2)



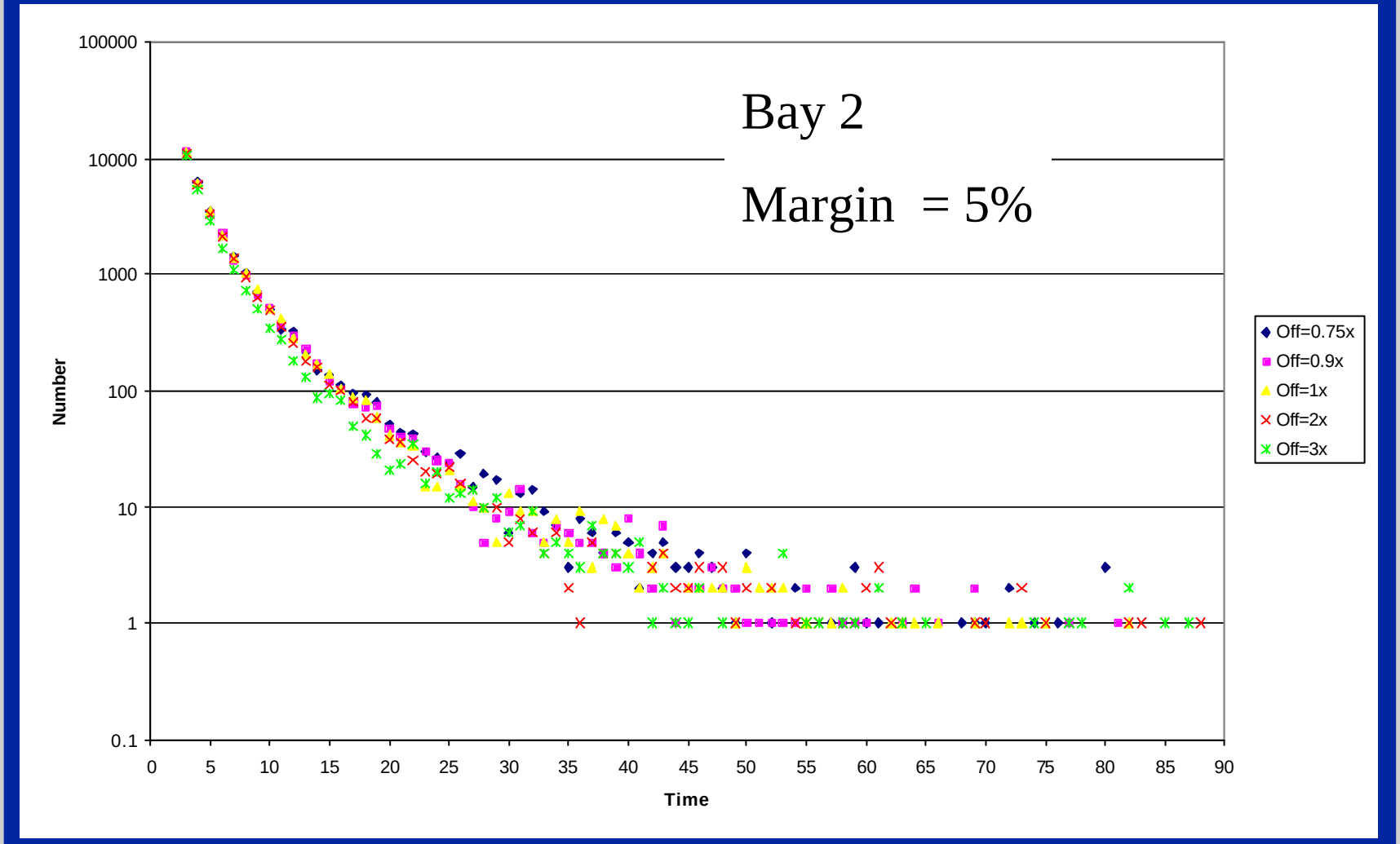
Balanced conditions for active power (3)



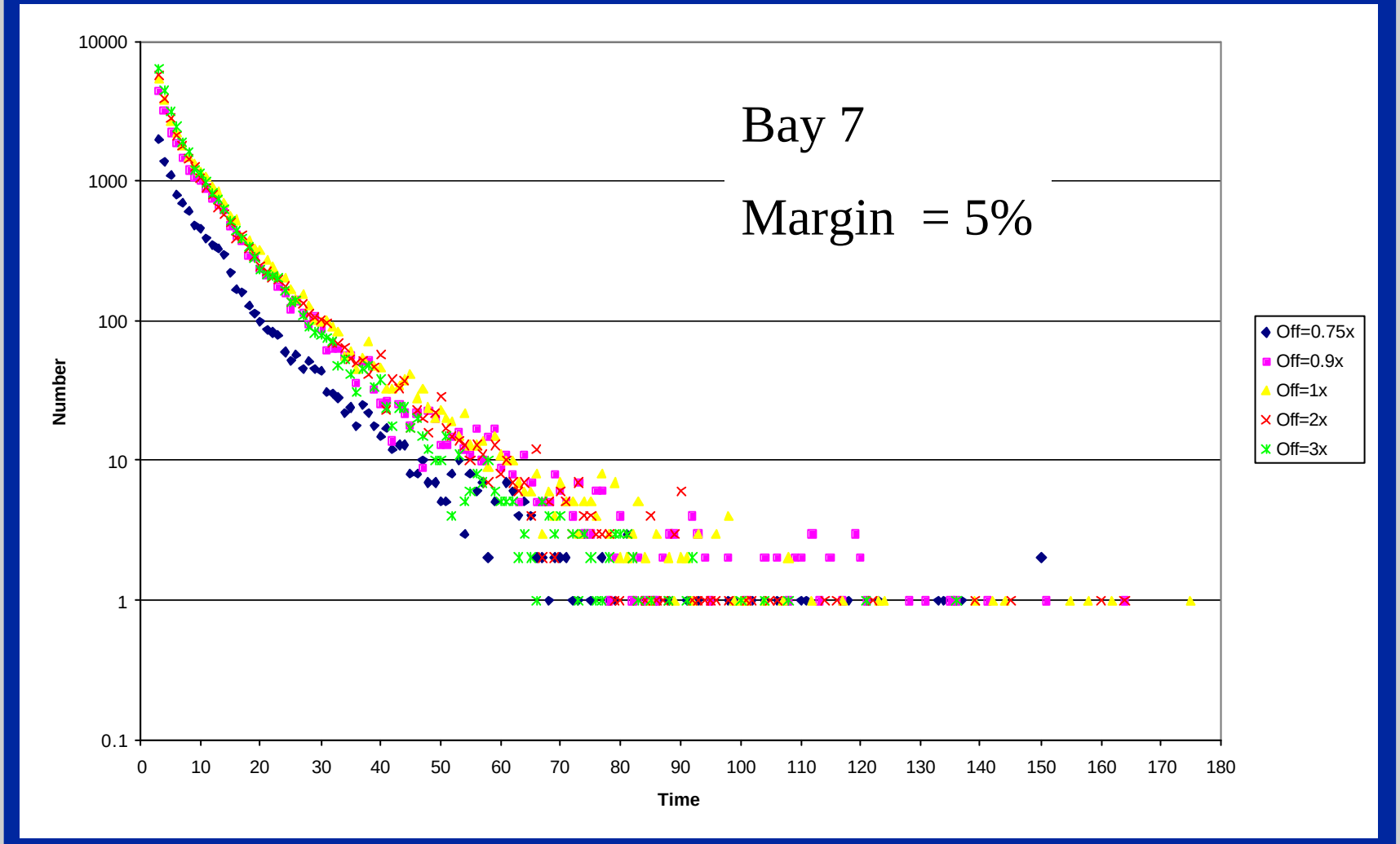
Balanced conditions for active power (4)



Balanced conditions for active power (5)



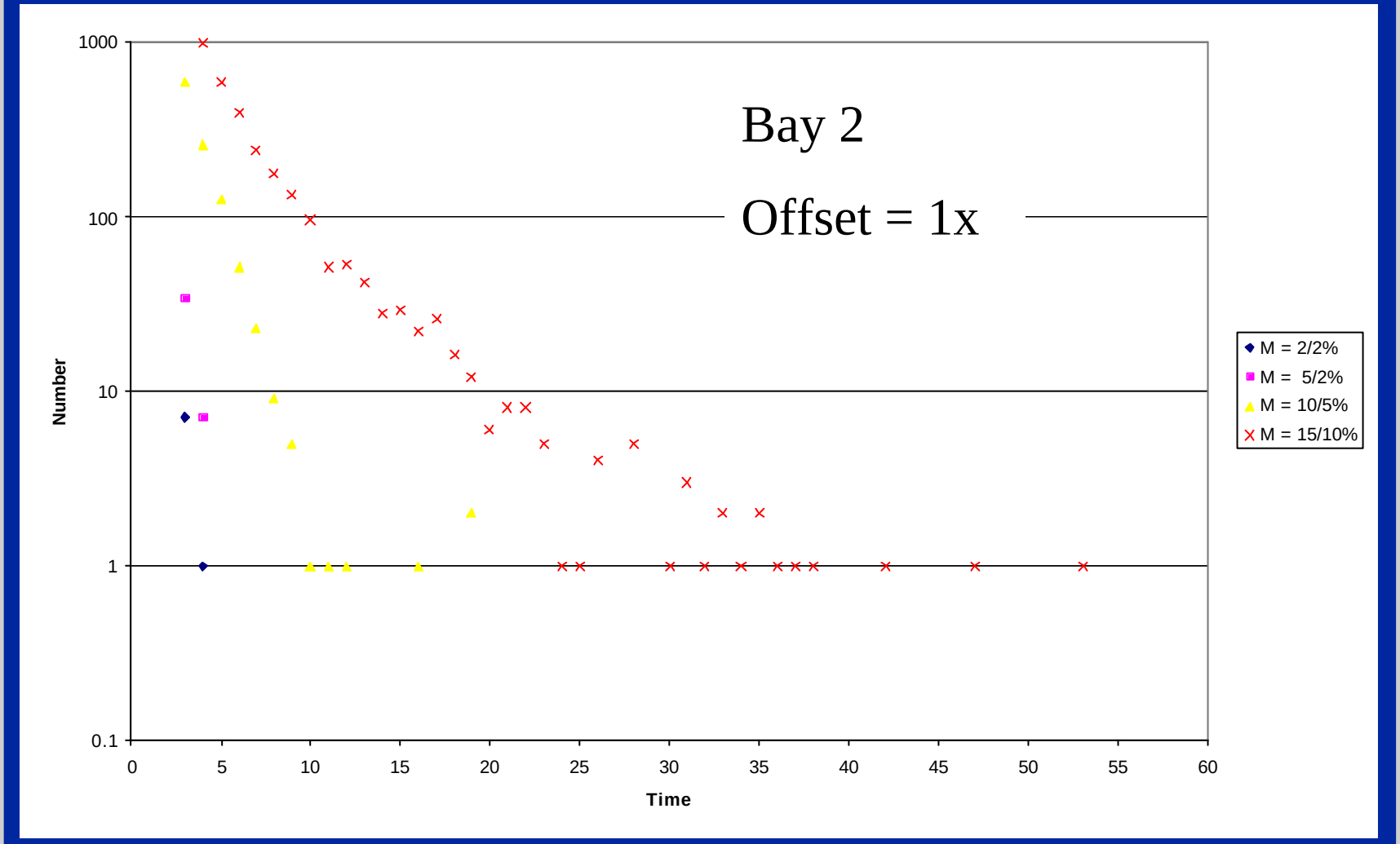
Balanced conditions for active power (6)



Balanced conditions for P and Q (1)

- In power networks balanced conditions for active and reactive power has to be present
- The reactive power consumption of the network is fairly constant
- The PV inverter must produce the reactive power as required by the load
- Balanced conditions for both active and reactive power occur very seldom

Balanced conditions for P and Q (2)



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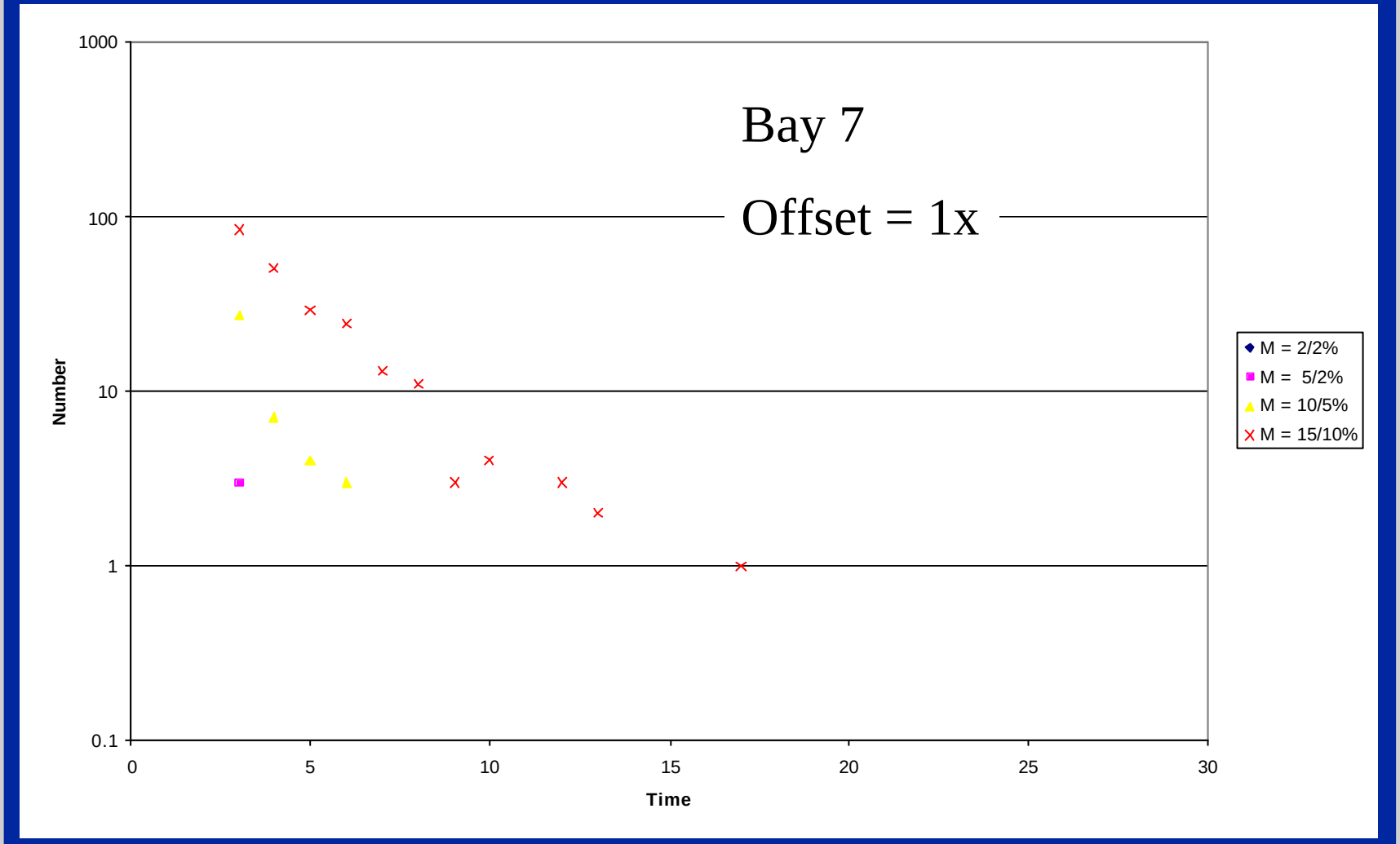

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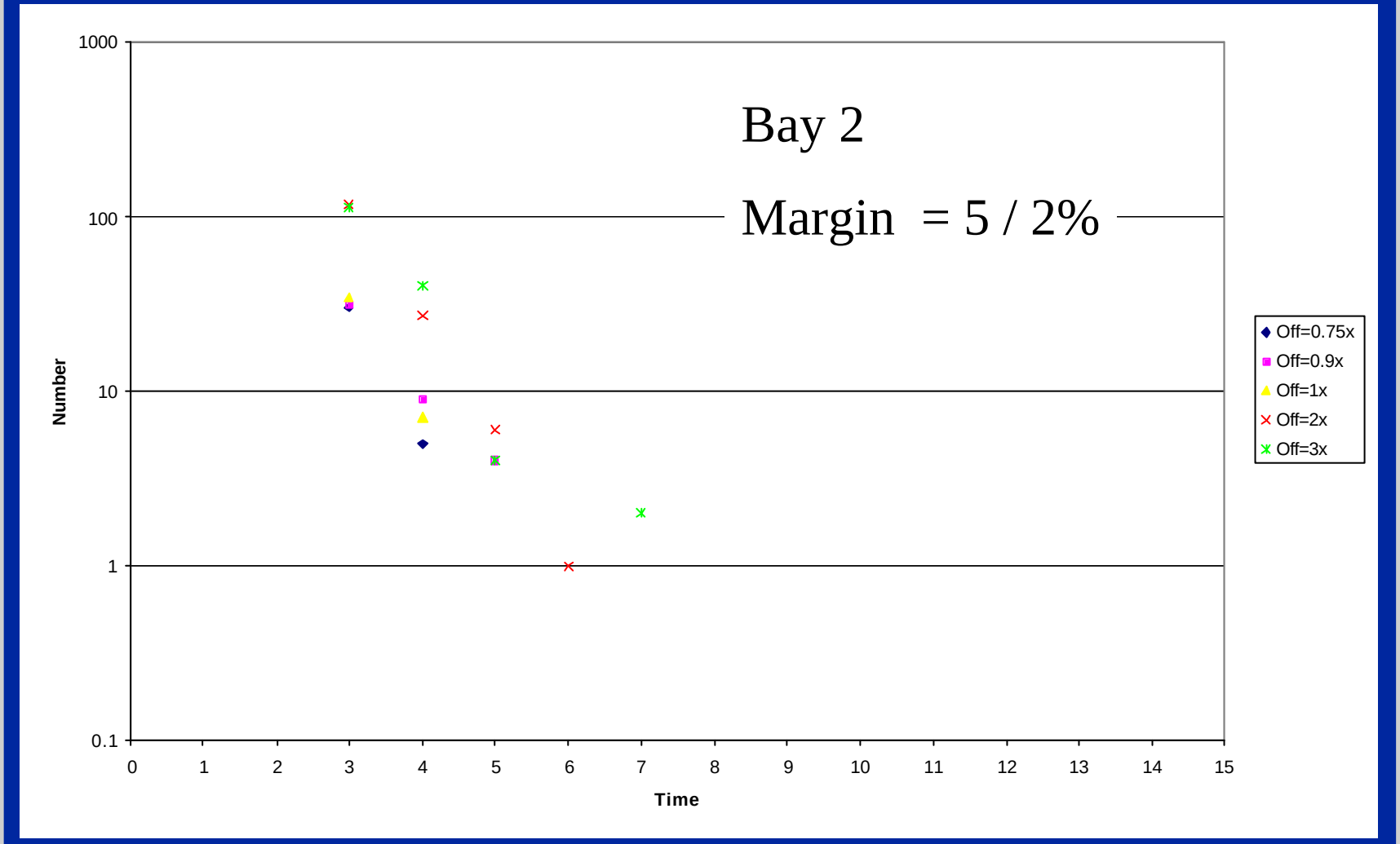

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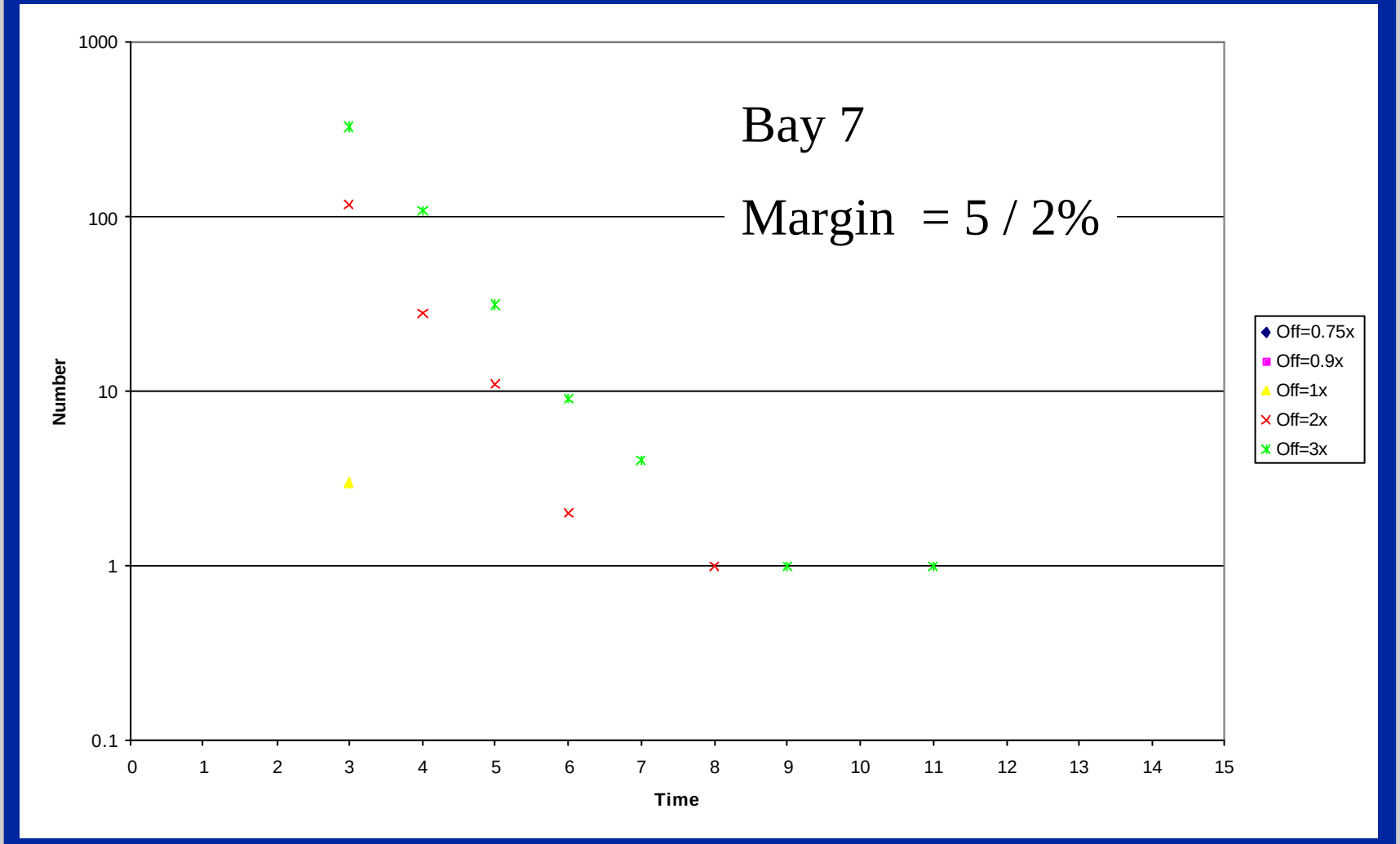


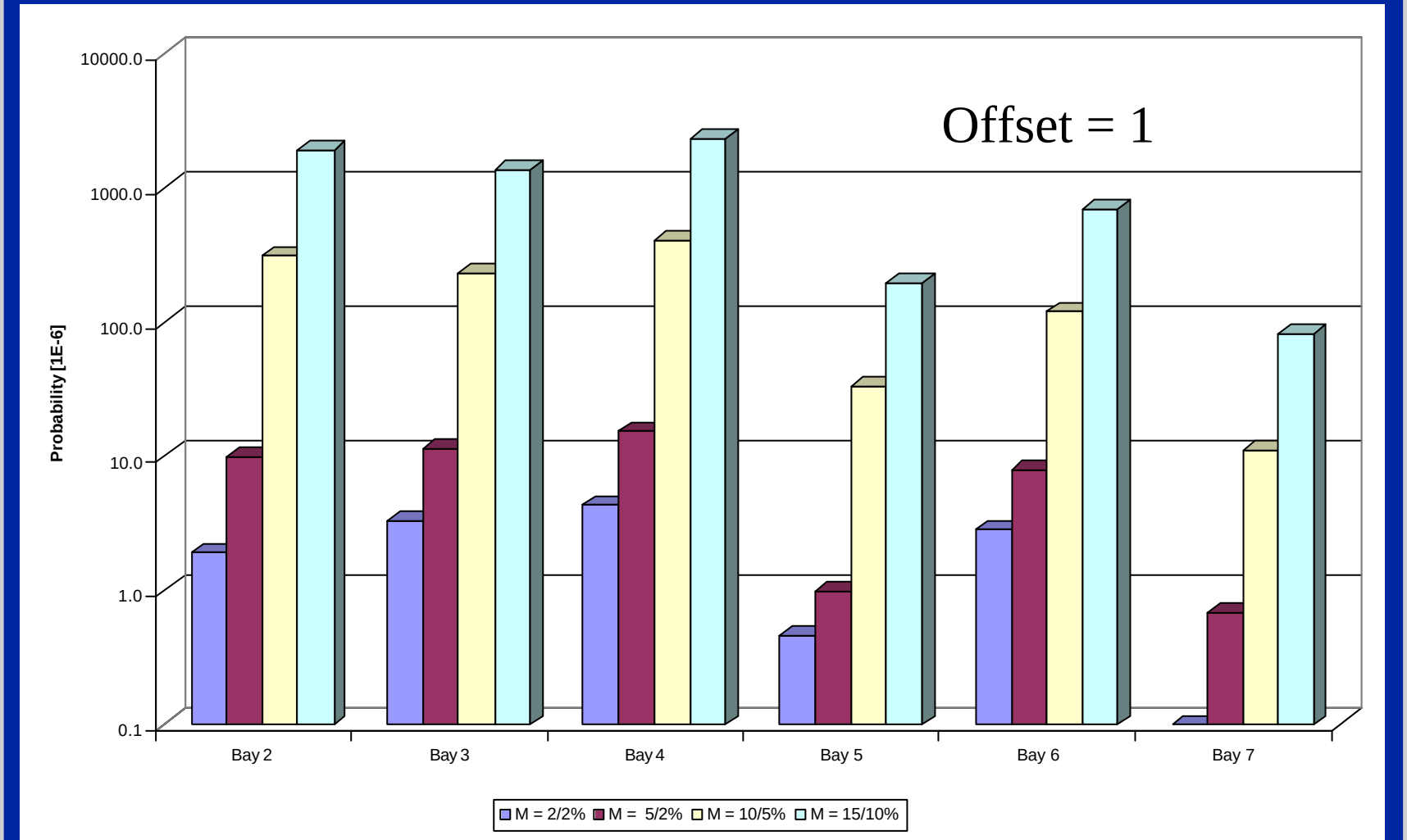
Probability of balanced conditions (1)

- Probability of islanding is defined as:

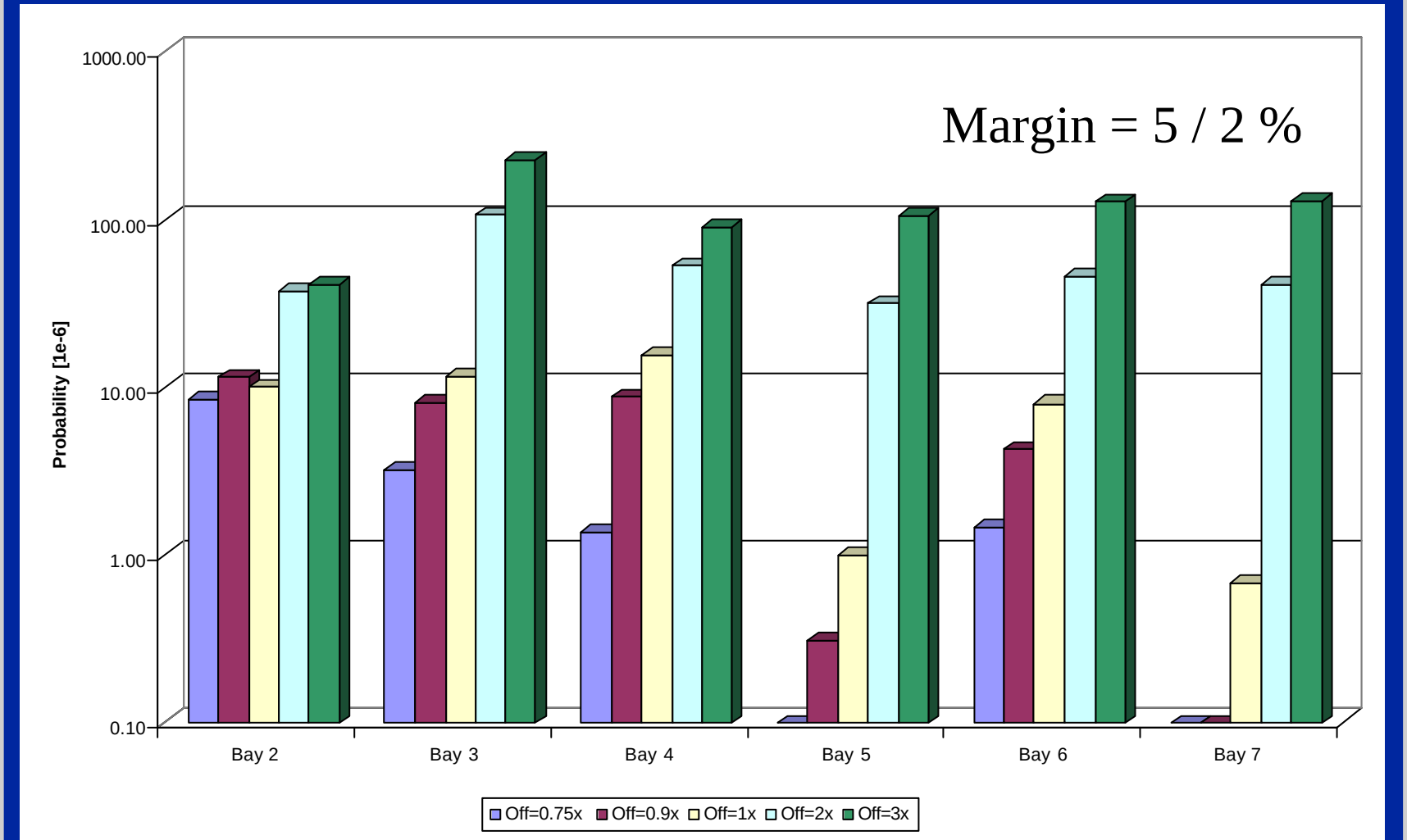
$$P = \frac{\text{å balanced condition x time}}{\text{Relevant seconds in year}}$$

- When assuming the relevant number of seconds as from 8.00 to 18.00 hour, we obtain for the year 13,14E6 seconds

Probability of balanced conditions (2)



Probability of balanced conditions (3)



Conclusions (1)

- Islanding does never occur up to a certain level of PV power
  - For Dutch situation this is 413 Wp per house
  - For loads with air-conditioners this will be significantly higher
- The maximum PV power that may be installed in a power network for which islanding does not occur is estimated at three times the minimum night load in that power network

Conclusions (2)

- The allowable mismatch between load and PV power significantly determines the number of balanced conditions
- Once above a threshold, the number of balanced conditions is not significantly influenced by PV penetration level
- Inverters should be fixed to operate at unity power factor
- A low voltage power network should not or only partially be compensated for its reactive power consumption

Conclusions (3)

The probability of balanced conditions in a certain part of a network is in the range

of 1E-6 to 1E-3 per year

x

The probability of that part of the network being disconnected with balanced conditions present and the protection is not working well is very small

x

Probability of encountering an islanding

is virtually zero