# Techniques for the Control of Steady State Voltage in MV and LV Networks

by

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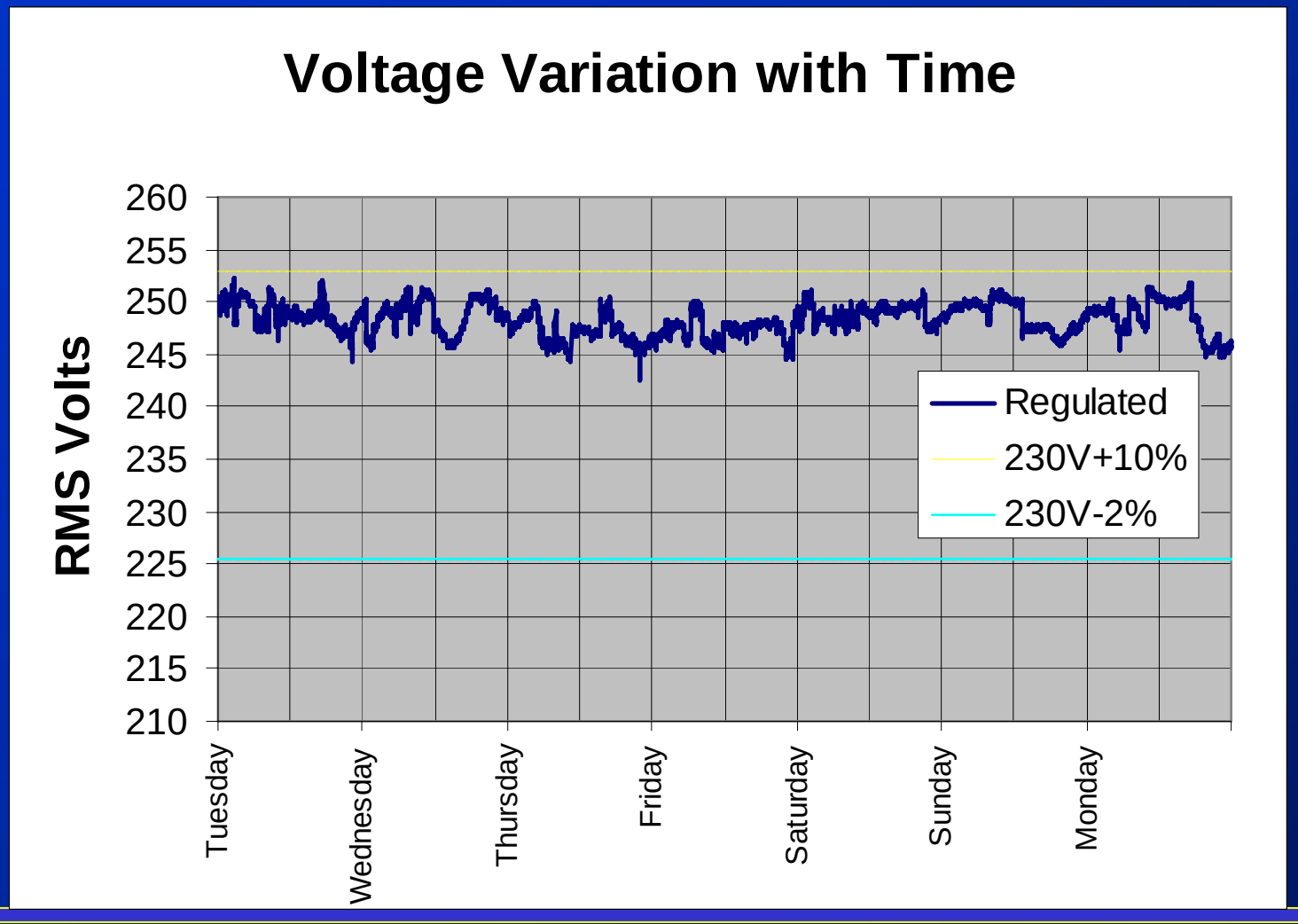
# Introduction

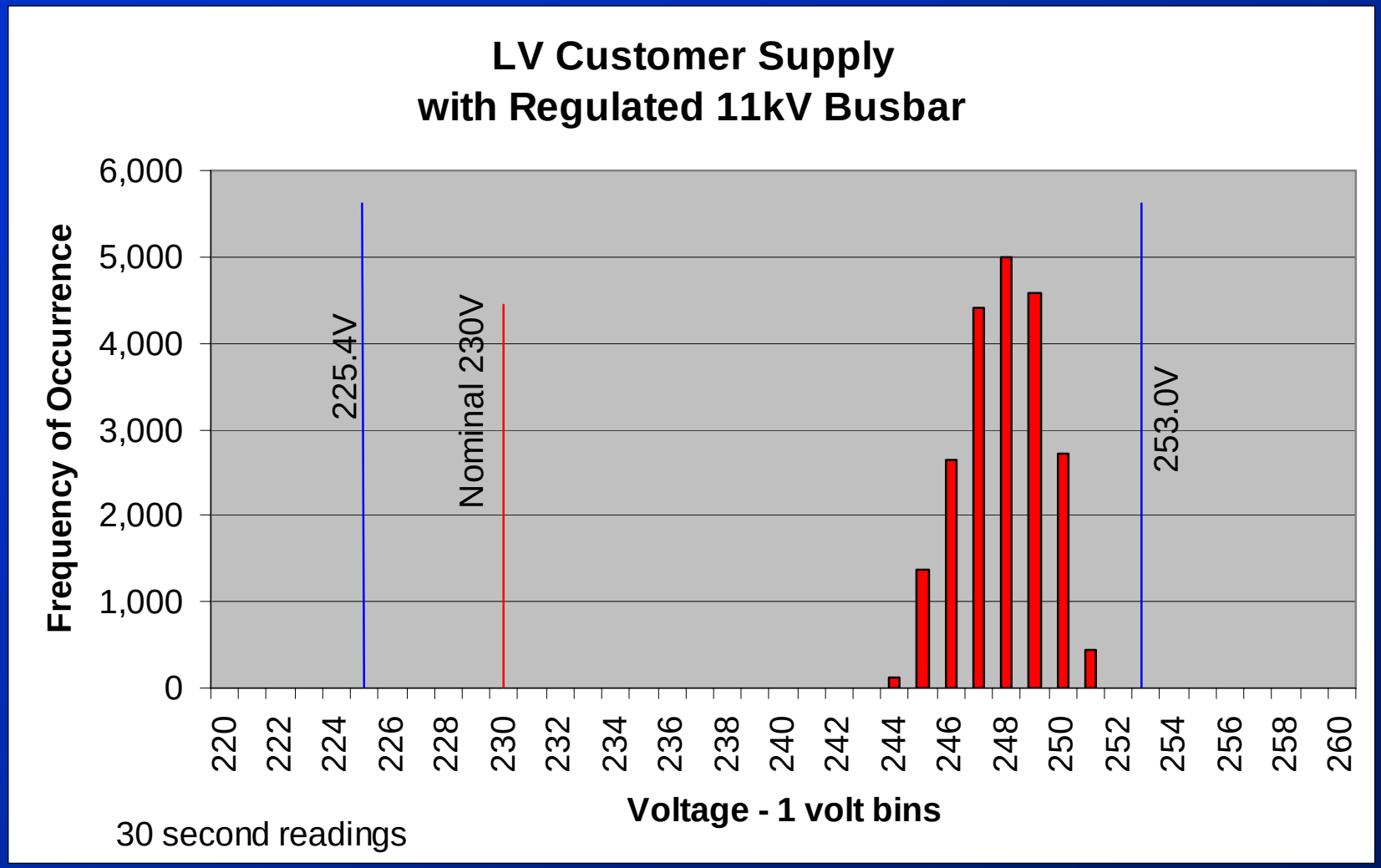
- Many Australian LV sites have poor LV steady state voltage performance
  - outside 230V-2%  to 230V+10% range
- Adverse impacts on customer equipment
  - performance and life
- In most cases steady state voltage performance can be improved with the application of simple principles and procedures
- This paper is a “how to” guide for distributors
- Achieve alignment with the Australian Steady State Voltage Standard that is currently under development

# The Ideal LV Supply
# 230V +10% - 2%

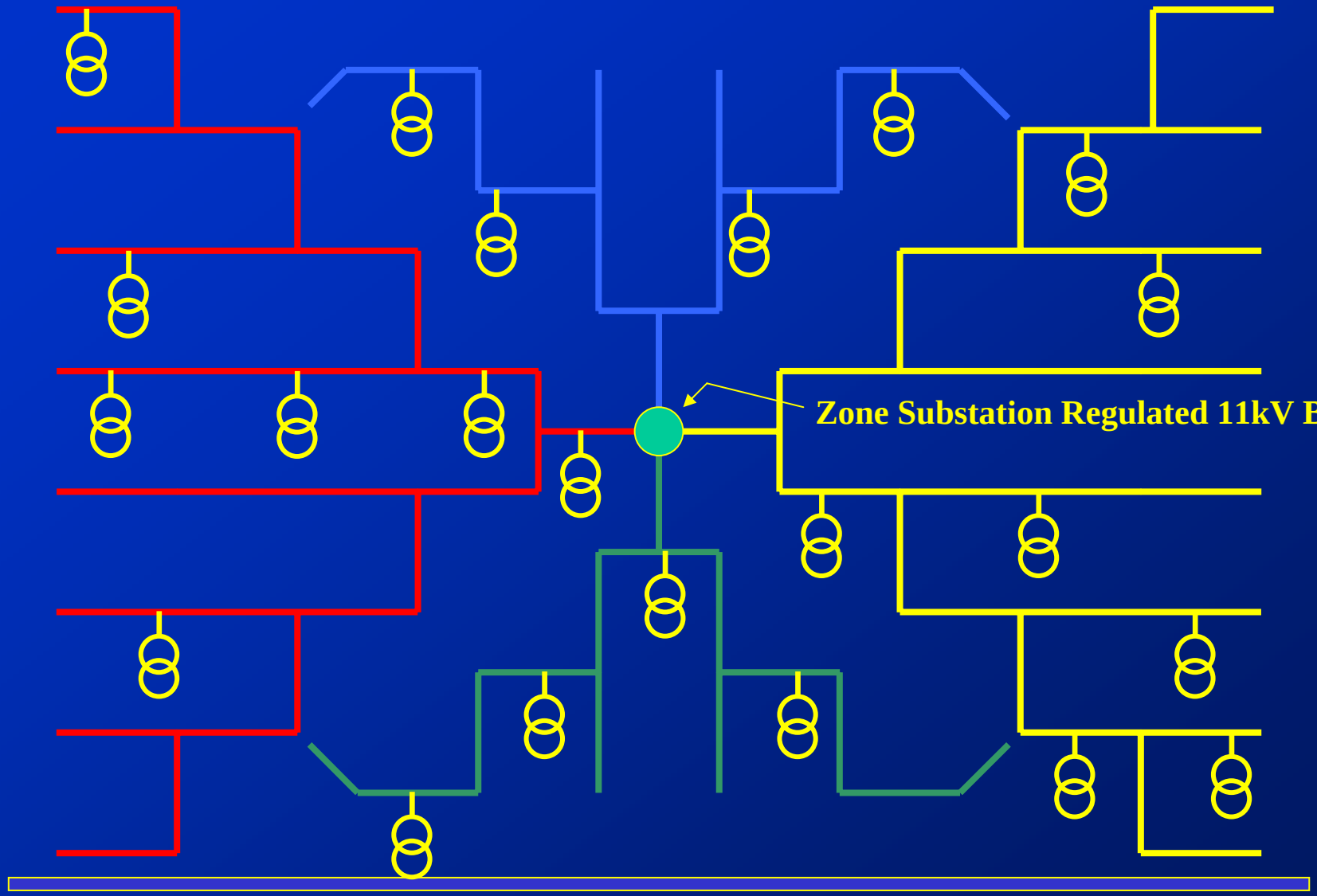
# Well Controlled LV Supply



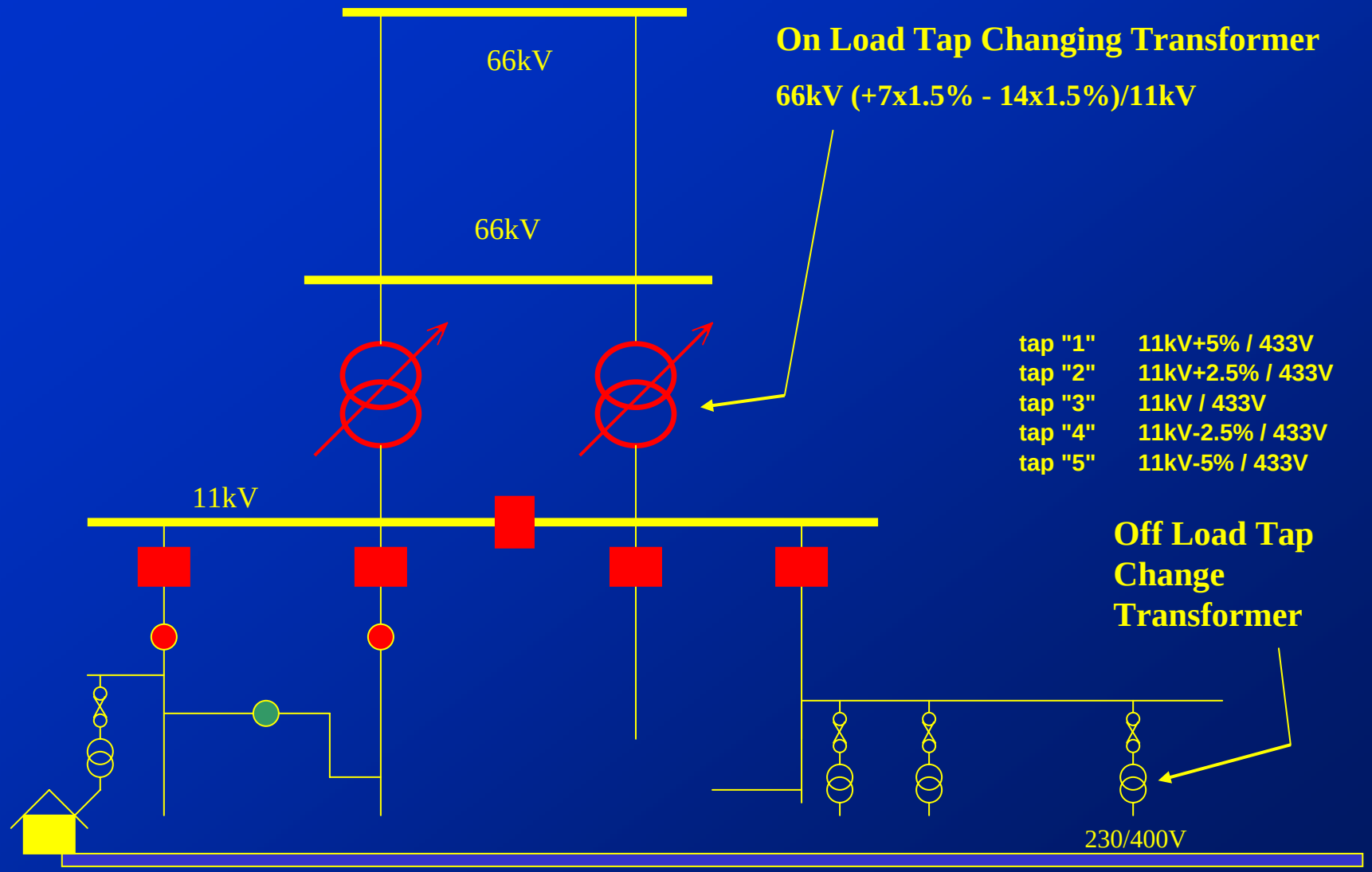
# Well Controlled LV Supply



# 11kV Feeder System



# Typical Network Arrangement



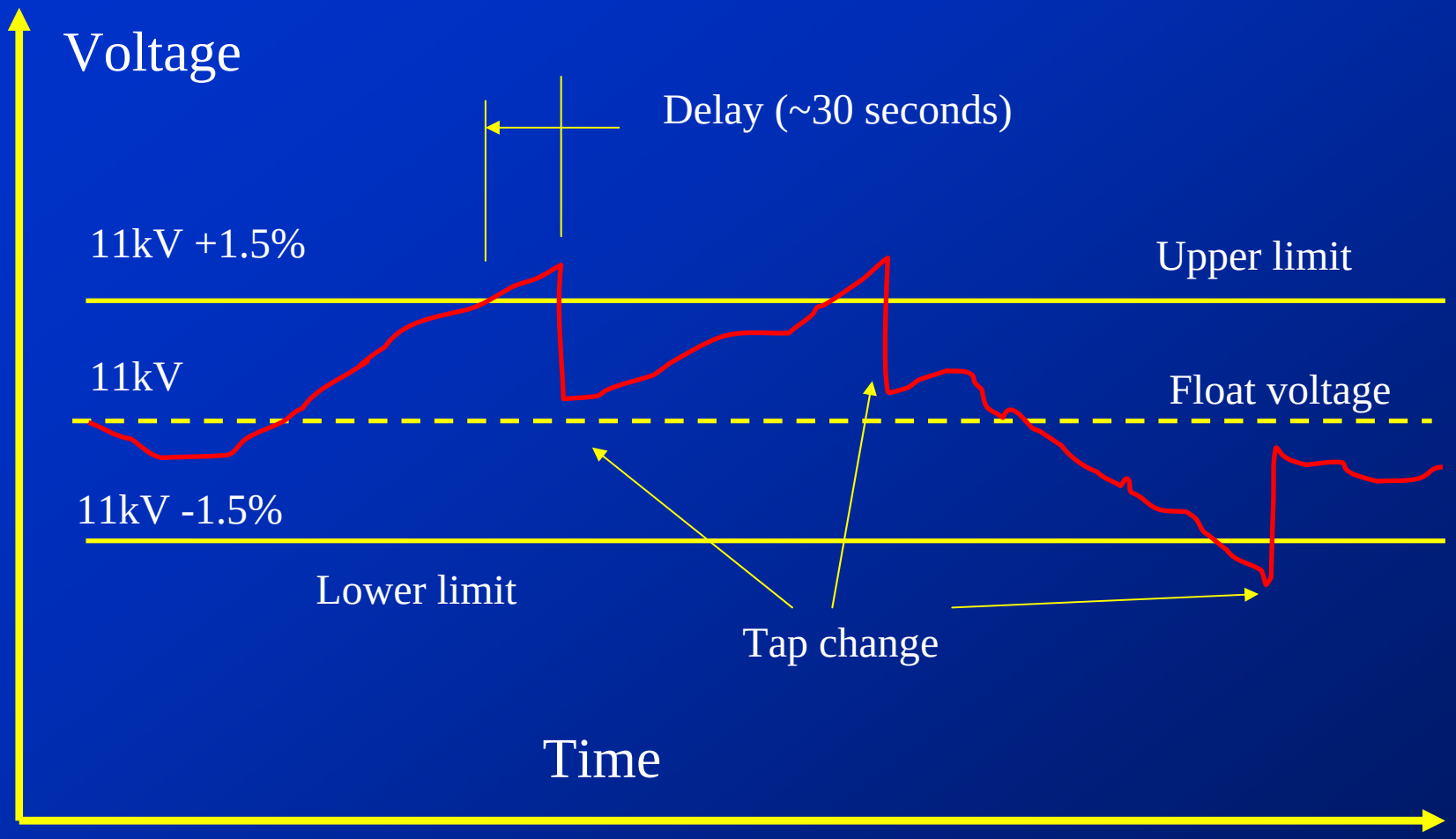

**On Load Tap Changing Transformer**

**66kV (+7x1.5% - 14x1.5%)/11kV**

| | |
|---|---|
| tap "1" | 11kV+5% / 433V |
| tap "2" | 11kV+2.5% / 433V |
| tap "3" | 11kV / 433V |
| tap "4" | 11kV-2.5% / 433V |
| tap "5" | 11kV-5% / 433V |

**Off Load Tap Change Transformer**

# OLTC Behaviour



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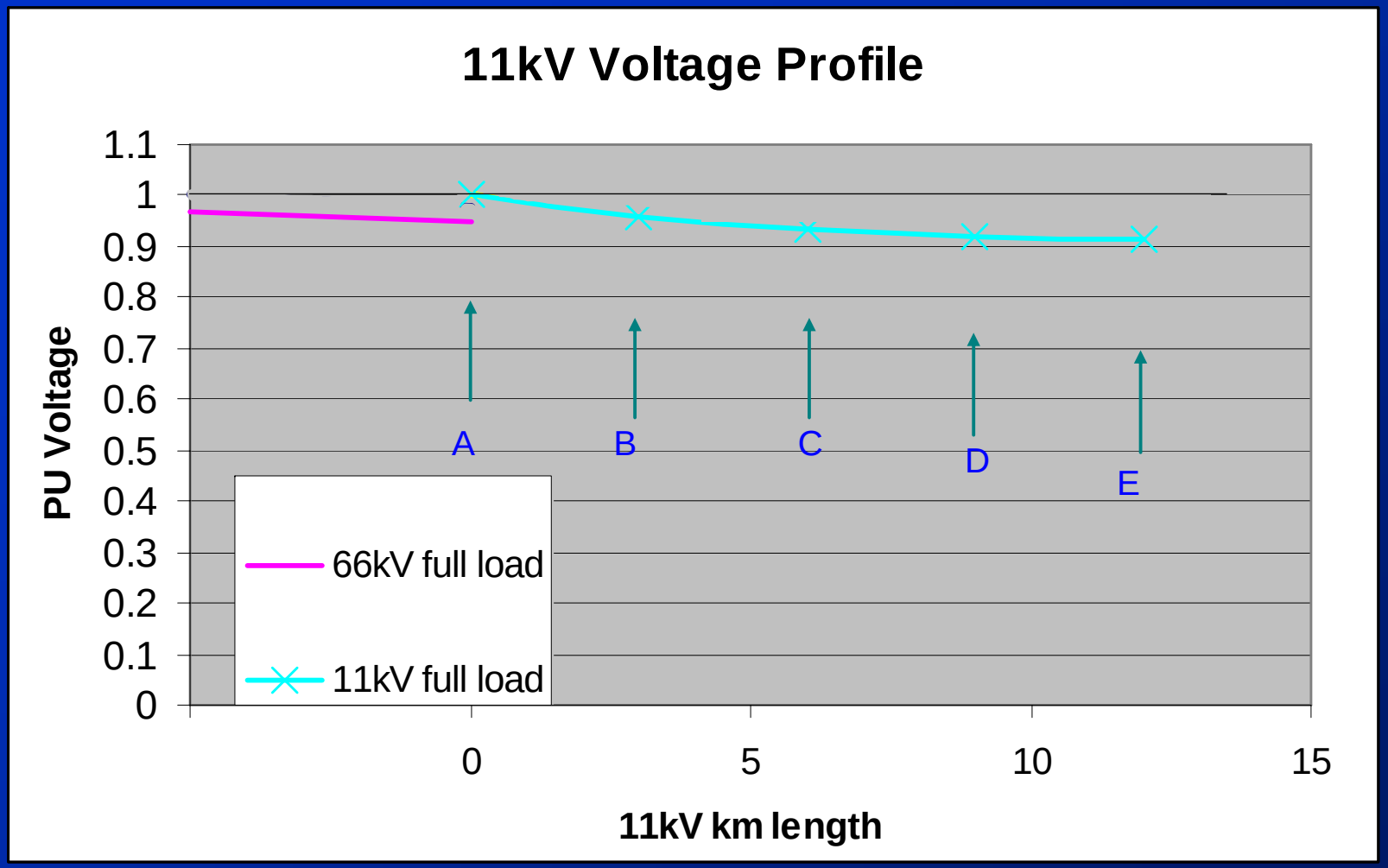

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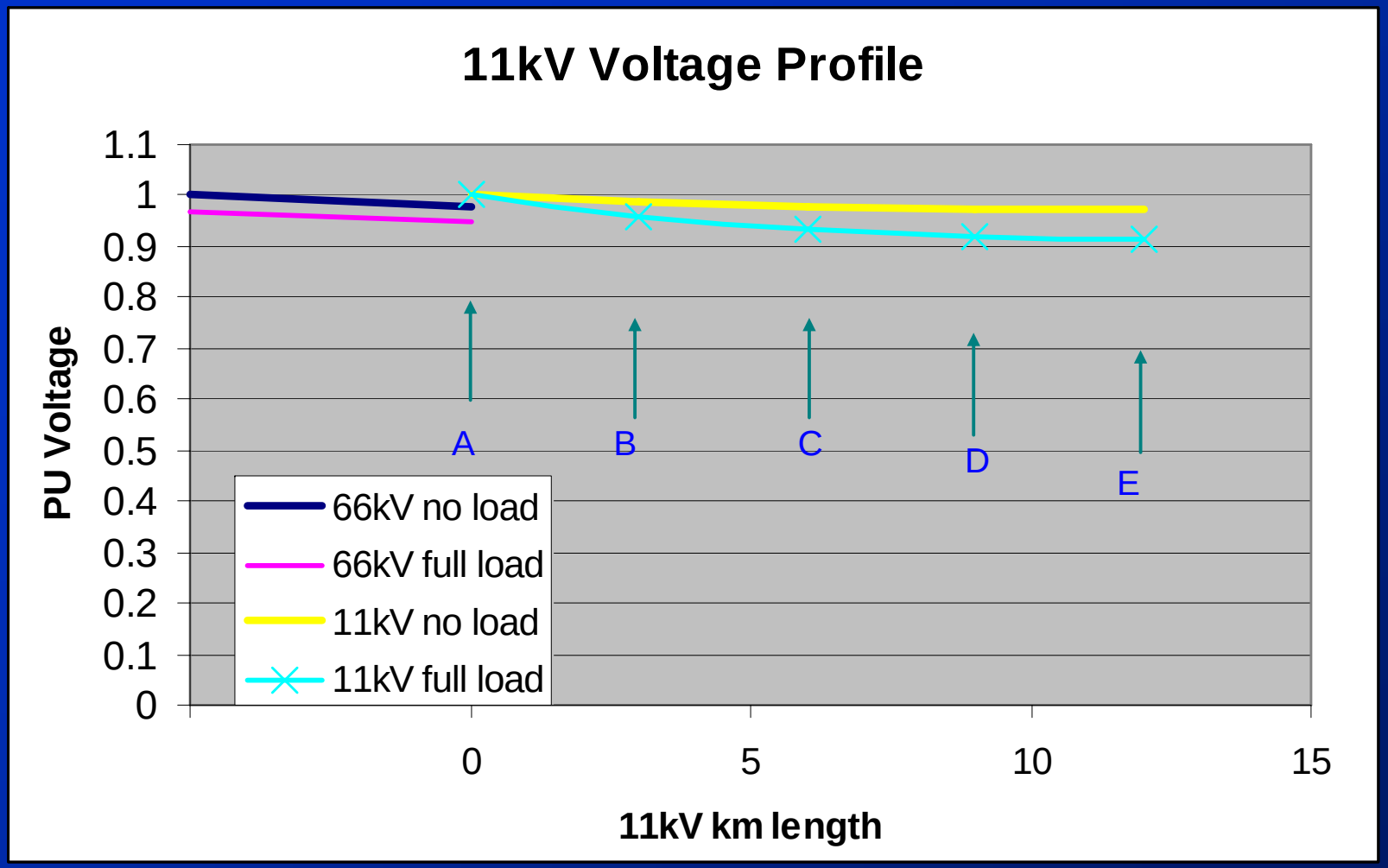

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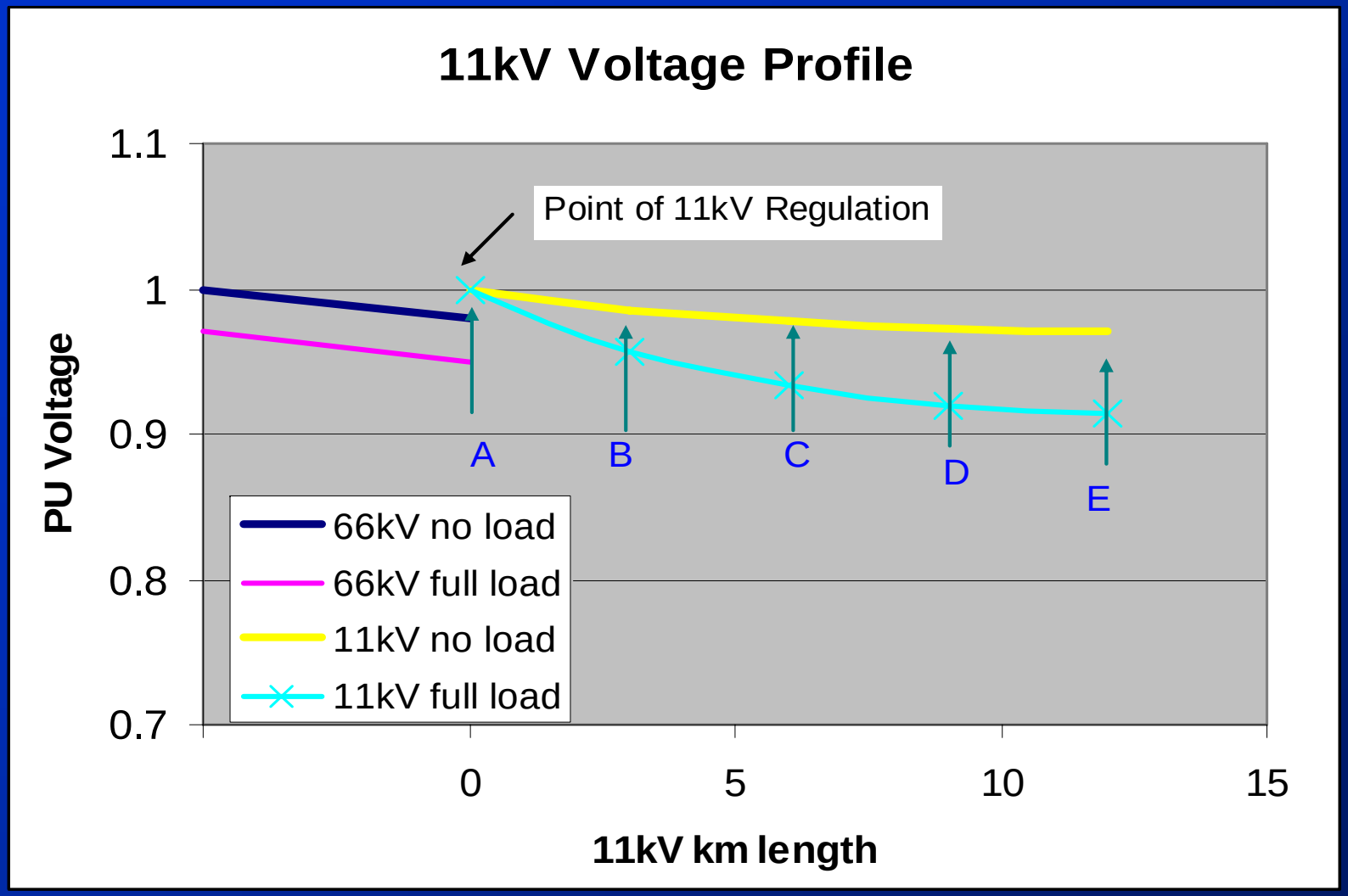
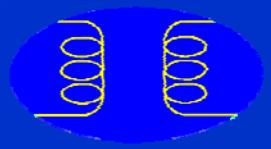


# Light Load Conditions

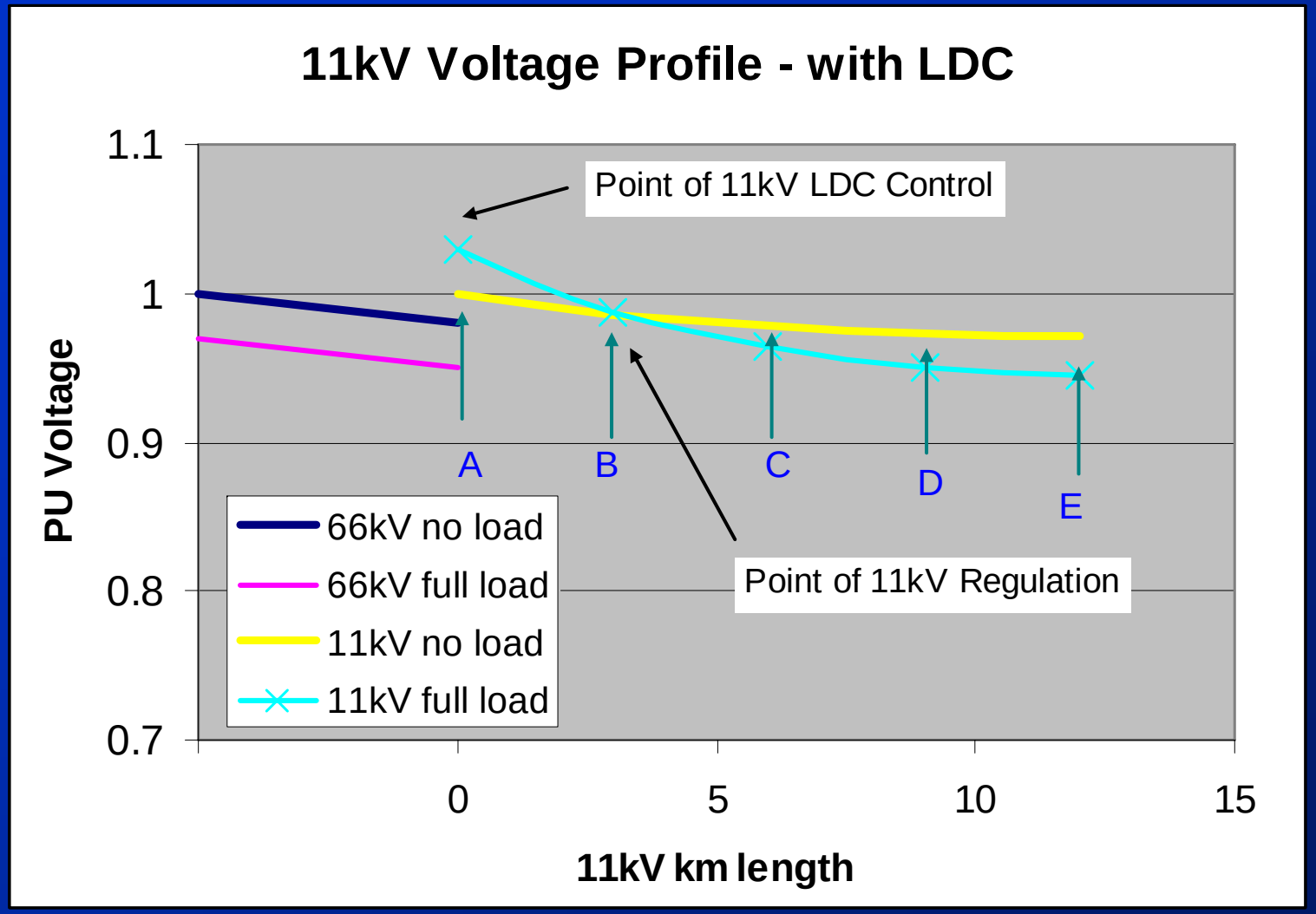
| Location | km from ZS | Light Load Voltage with 11kV±1.5% at regulated 11kV busbar | | | | |
|---|---|---|---|---|---|---|
| | | tap 1 | tap 2 | tap 3 | tap 4 | tap 5 |
| A | 0 | 241.7 | 247.6 | 253.7 | 260.2 | 267.1 |
| B | 3 | 238.2 | 244.0 | 250.1 | 256.5 | 263.3 |
| C | 6 | 236.4 | 242.1 | 248.2 | 254.6 | 261.3 |
| D | 9 | 235.2 | 241.0 | 247.0 | 253.3 | 260.0 |
| E | 12 | 234.8 | 240.5 | 246.5 | 252.8 | 259.5 |



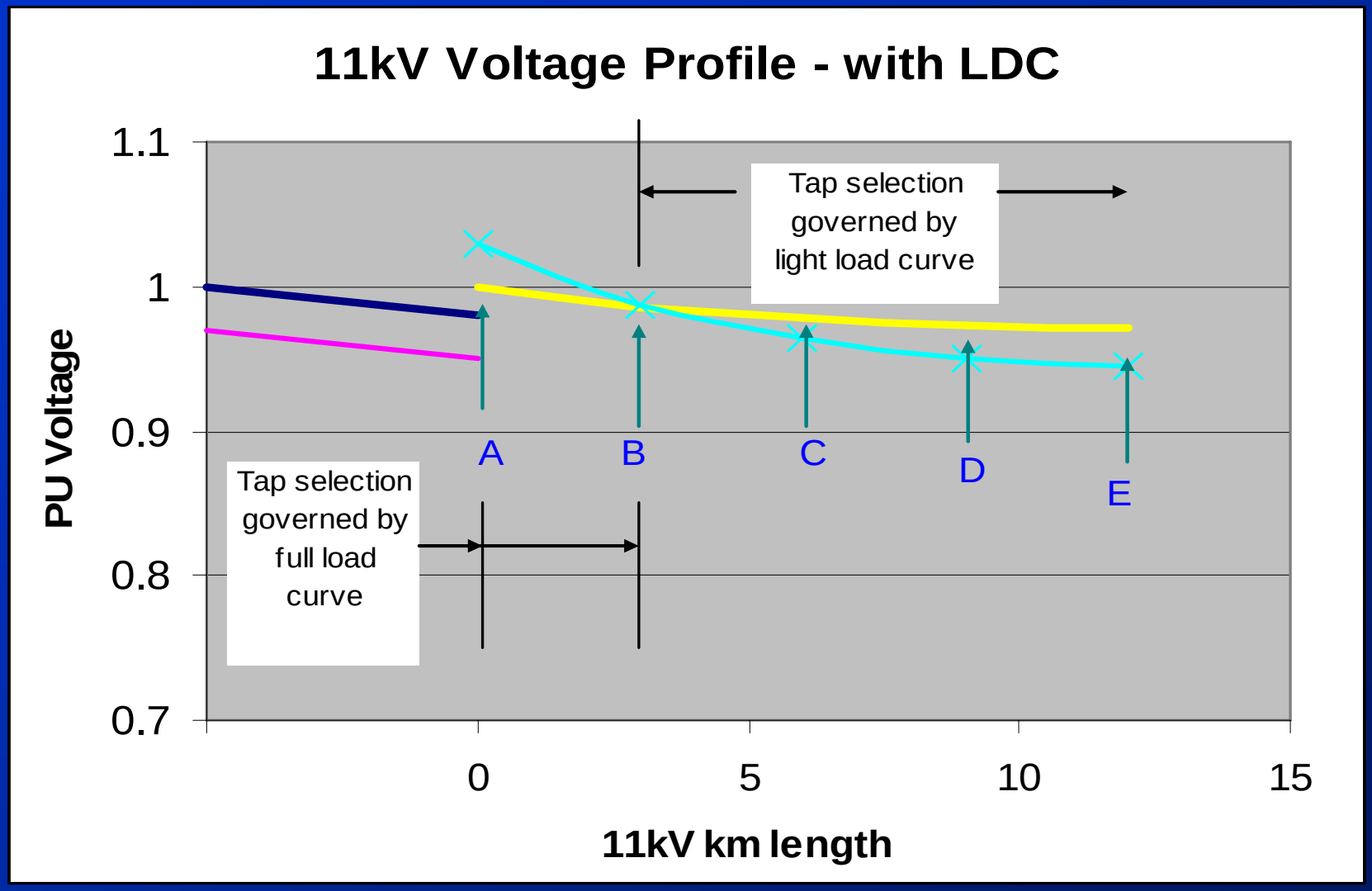
# Full Load Conditions

| Location | km from ZS | Full Load Voltage | | | | |
|---|---|---|---|---|---|---|
| | | tap 1 | tap 2 | tap 3 | tap 4 | tap 5 |
| A | 0 | 234.5 | 240.2 | 246.2 | 252.6 | 259.2 |
| B | 3 | 224.5 | 230.0 | 235.7 | 241.8 | 248.1 |
| C | 6 | 219.1 | 224.5 | 230.1 | 236.0 | 242.2 |
| D | 9 | 215.8 | 221.1 | 226.6 | 232.4 | 238.5 |
| E | 12 | 214.5 | 219.7 | 225.2 | 231.0 | 237.0 |

# Line Drop Compensation



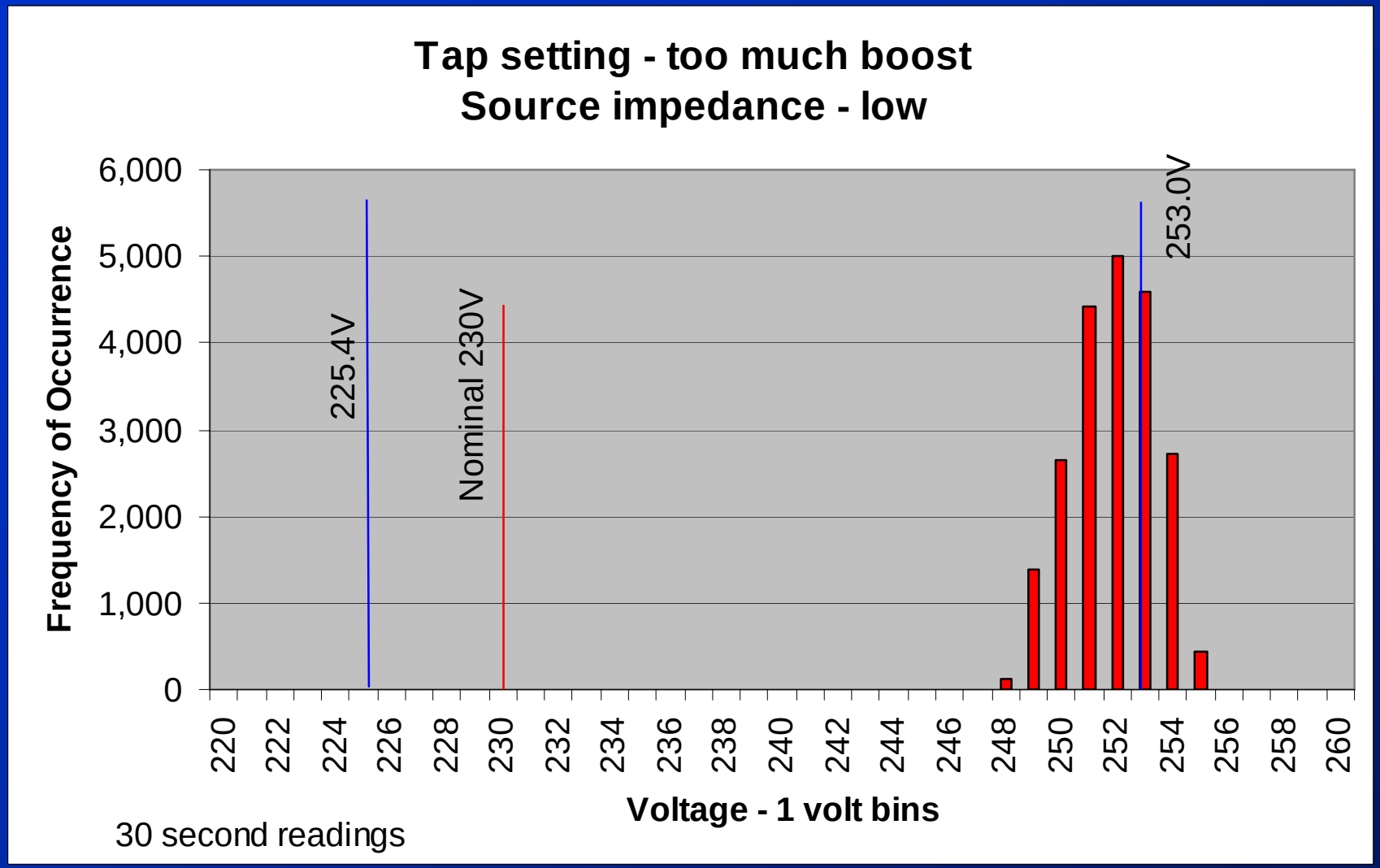
# LDC – Tap Selection



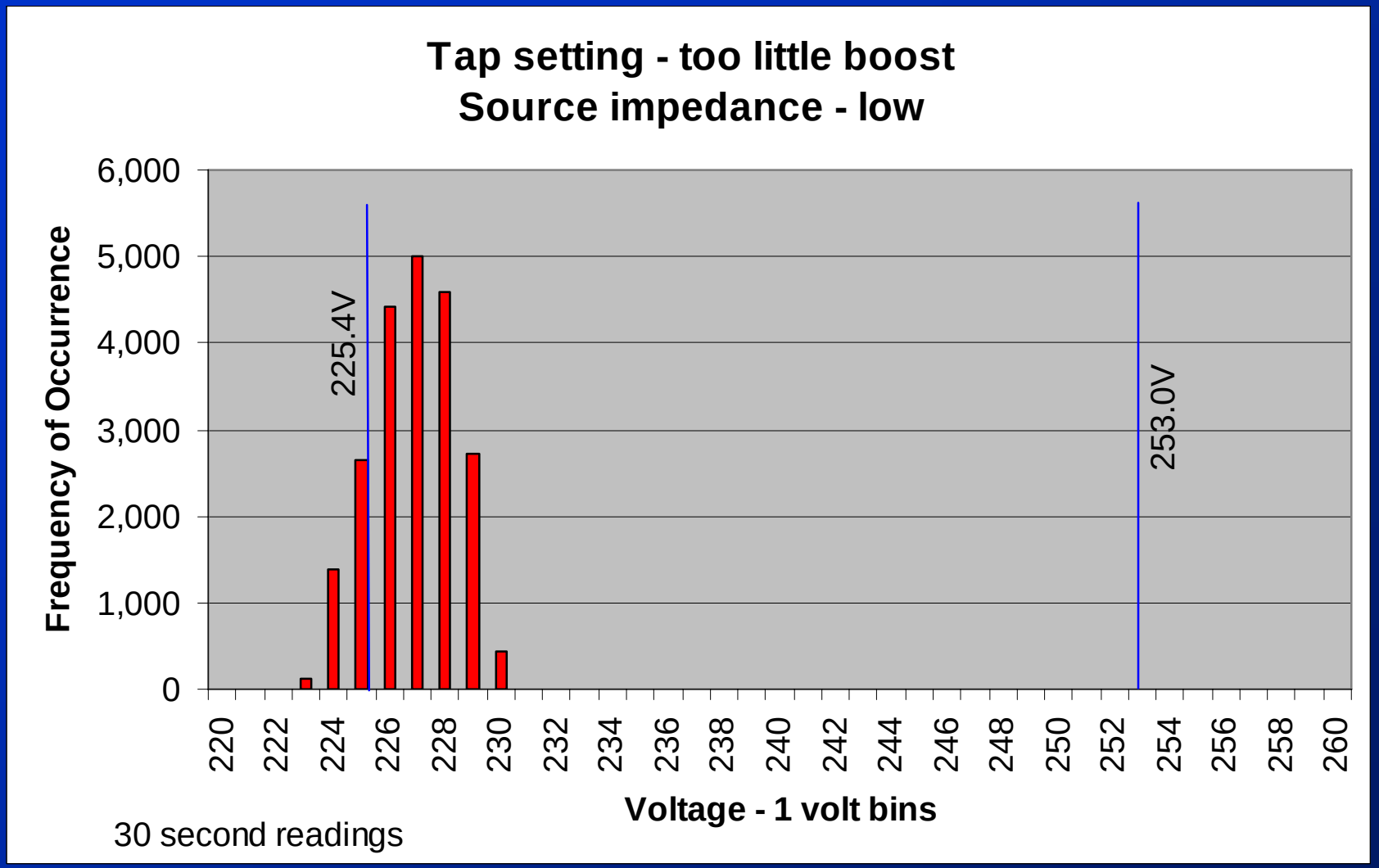
# Tap Selection with LDC

| Location | km from ZS | Voltage - 11kV with LDC | | | | |
|---|---|---|---|---|---|---|
| | | tap 1 | tap 2 | tap 3 | tap 4 | tap 5 |
| A light load | 0 | 238.1 | 243.9 | 250.0 | 256.4 | 263.2 |
| A full load | 0 | 245.2 | 251.2 | 257.5 | 264.1 | 271.0 |
| | | | | | | |
| B light load | 3 | 232.9 | 238.6 | 244.5 | 250.8 | 257.4 |
| B full load | 3 | 235.1 | 240.8 | 246.8 | 253.1 | 259.8 |
| | | | | | | |
| E light load | 12 | 231.3 | 236.9 | 242.9 | 249.1 | 255.7 |
| E full load | 12 | 224.9 | 230.4 | 236.1 | 242.2 | 248.5 |

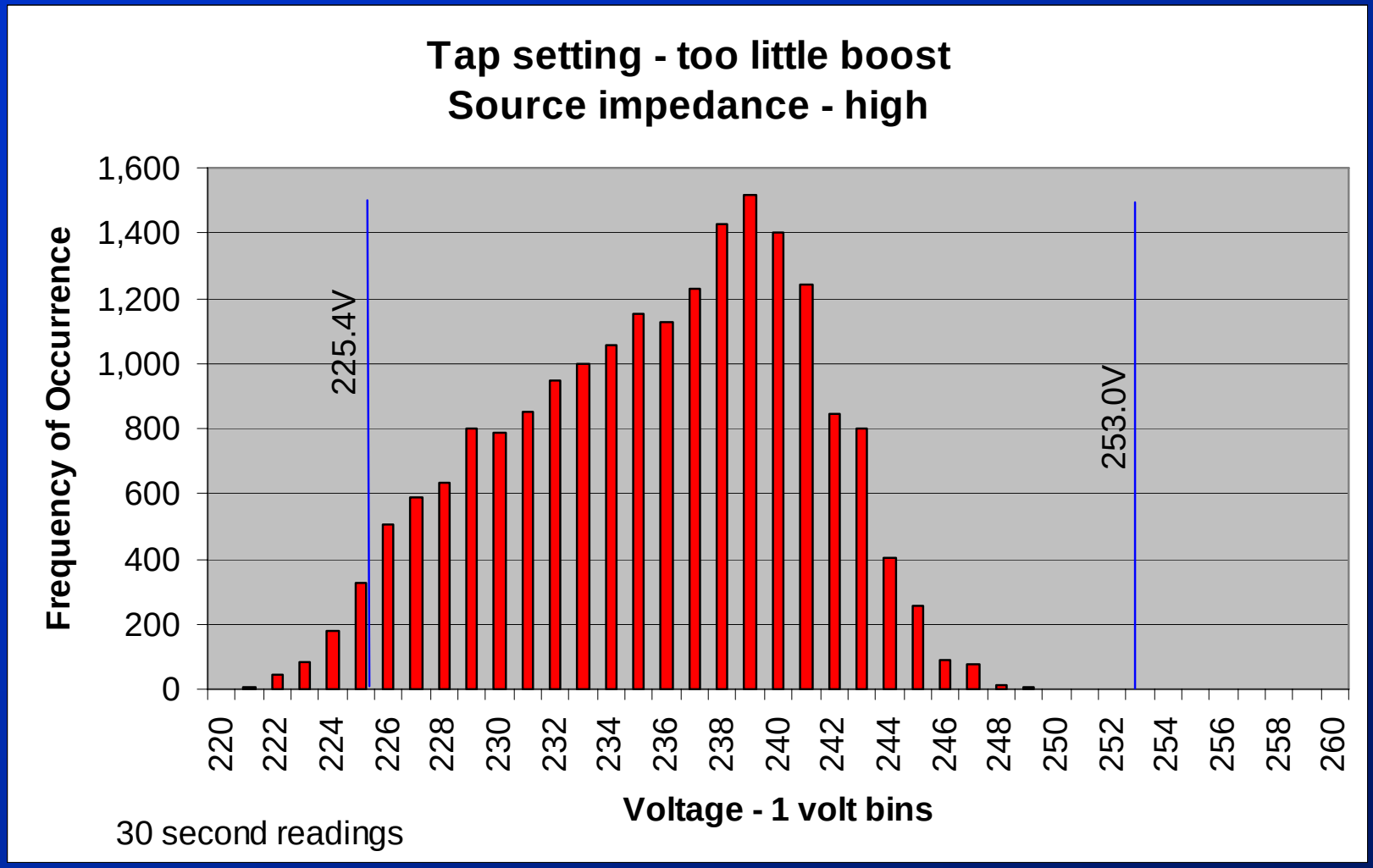
# Voltage Signature 1



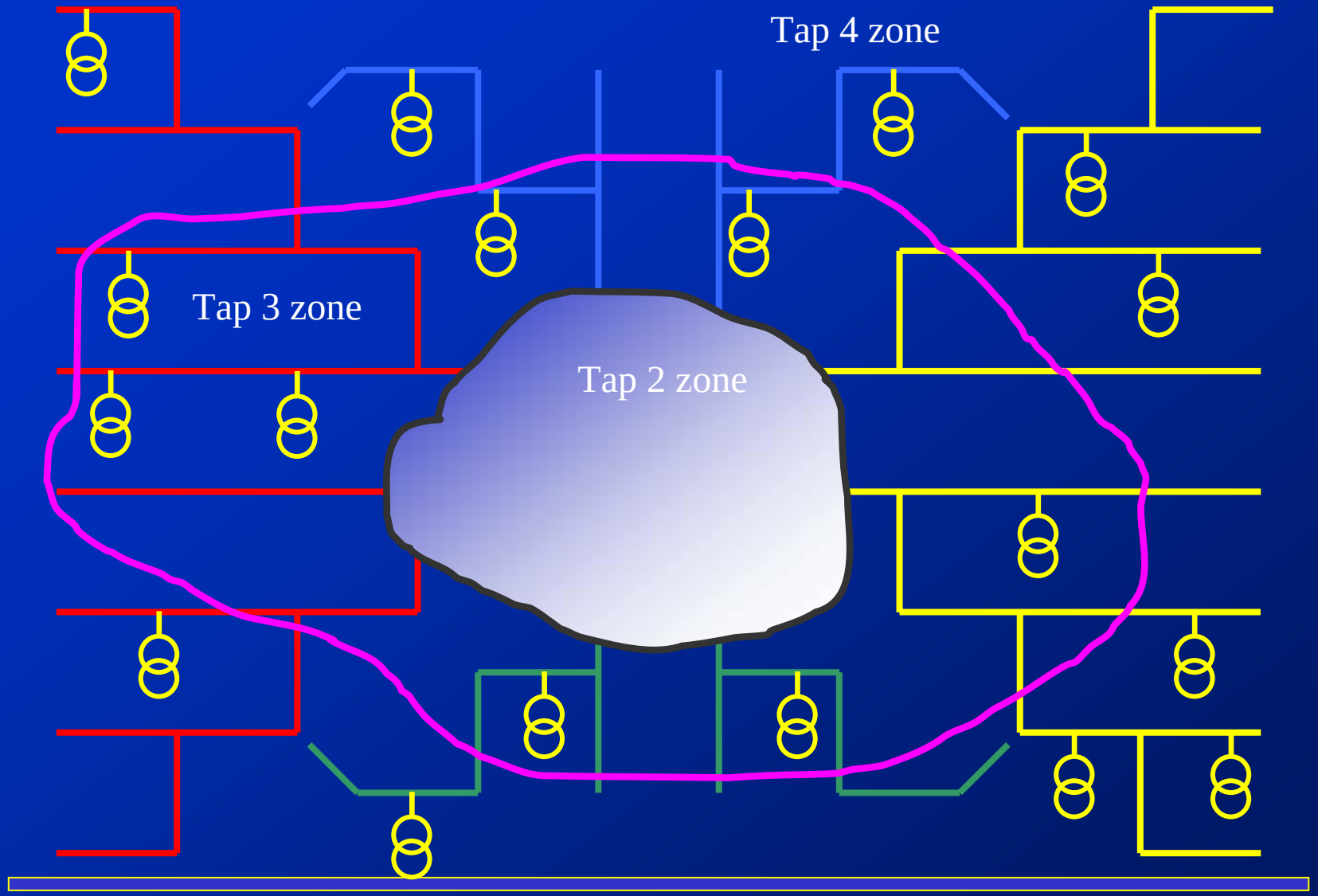
# Voltage Signature 2



# Voltage Signature 3



# 11kV Tapping Zones



# Best Practice Procedures

- Electricity distributors need clear voltage control objectives and processes
- OLTC transformer float, bandwidth, time delay method, time delay and LDC settings need to be carefully selected, documented and implemented
- Consider time delay methods - fixed, inverse or integrated:
  - tap changer operations and maintenance
  - restores voltage levels quicker in response to large load changes e.g. due to a feeder trip
  - consider fast tap changer response – capacitor switching
  - grading with upstream OLTC transformer operation (hunting)
- Light load and full load MV distribution profiles (11kV & 22kV) need to be modelled on a regular basis – say every 2 years
  - particularly where LDC is used – volts can creep up with load growth

# Best Practice Procedures

- Based on VRR settings & voltage profile
  - allocate a tap setting for every distribution transformer via tapping zone plans
- Field staff
  - implement distribution tap setting at every maintenance or other opportunity
  - understand practices
  - information and training sessions needed
- VRR and tap settings
  - No unauthorised adjustment
  - Voltage regulating relays need to be carefully set and tested on a regular basis
- Monitoring of network voltages
  - essential to ensure proper control is being achieved

# Operational Issues

- Alternate switching configurations
  - can adequate voltage levels be maintained?
  - isolate supply if voltage cannot be maintained between predetermined limits
  - be careful of LDC impacts with load transfers
- OLTC transformer operation
  - be prepared for possible VRR maloperation
  - if necessary limit OLTC range to prevent extreme under or over voltage conditions
- Distribution transformers issues
  - inconsistent taping ratios
  - incompatible tapping ranges
  - different tap names
  - be prepared to scrap incompatible transformers
- Embedded generation and switched field capacitor banks
  - Requires special consideration on the voltage profiles and voltage control strategies
- Routine monitoring of strong and weak sites

# Conclusions

- There are considerable customer benefits to be gained by improving voltage control in many distribution networks
  - extended equipment life
  - better equipment performance
  - Compliance with standards

- Achieving voltage control:
  - is not technically difficult - no rocket science required
  - clear objectives
  - requires discipline and good engineering systems
  - requires both office staff and field staff cooperation and coordination
  - optimises use of network assets
  - can defer the need for capital expenditure
  - is an essential part of good network planning
  - can be achieved at low cost