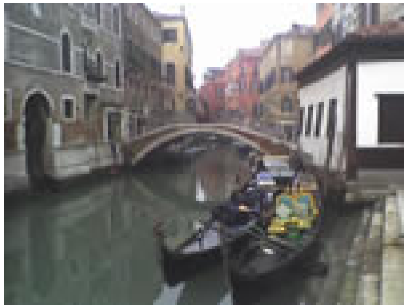
UIE working group
Power Quality

Voltage Dip Immunity of Equipment and Installations



The First International Conference on Smart Grids, Green Communications and IT Energy-aware Technologies

ENERGY 2011

May 22-27, 2011 - Venice/Mestre, Italy

TUTORIAL

Equipment and Processes Immunity

(Part 3)

Equipment/Process Dip Immunity

- Review of equipment behaviour and responses to voltage dips
  - What is reported in literature?
  - Experience of Working Group members
  - Is the information complete?
  - How this information should be presented?
- Overview of process immunity
  - How do typical processes react to dips?
  - Identification of the most critical equipment

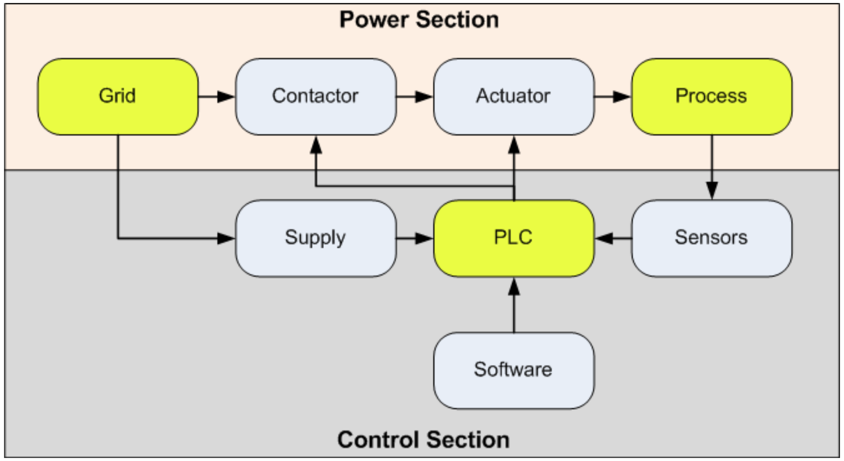
Equipment Behaviour

❑ Parameters of influence:

- Voltage supply related parameters
  - Pre-dip: voltage magnitude, distortion, unbalance…
  - During-dip: dip type, shape, depth, duration, segments...
  - Post-dip: voltage recovery, inrush current, distortion…
  - Network topology: source impedance, presence of other equipment
- Equipment specific parameters
  - Hardware topology, operation mode, parameter settings, loading
- Non-electrical parameters
  - Temperature, humidity, presence of vibrations...

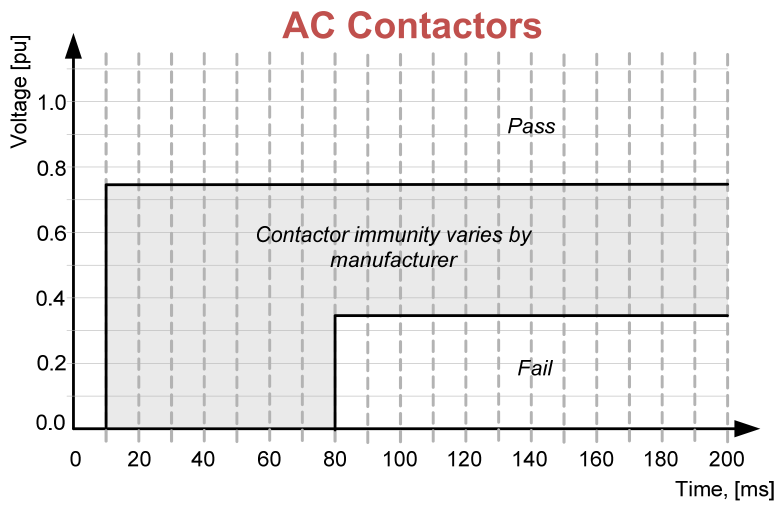
Equipment Behaviour

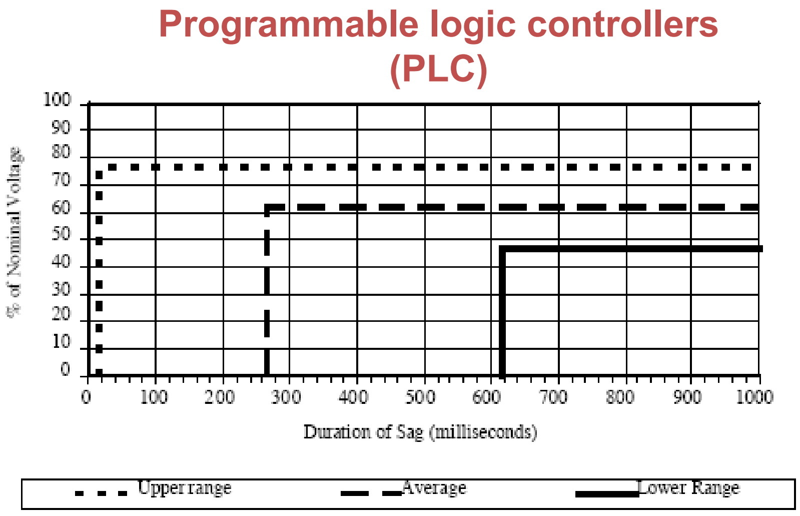
- As mentioned, lot of parameters involved
- Each piece of equipment can be considered unique (together with its environment)
- Single representation, using e.g. a voltage tolerance curve, is often not sufficient
- Literature mainly focuses on dip parameters
- Example Process →



Equipment Behaviour: Results

“Best and Worst Case” volt. tolerance curves

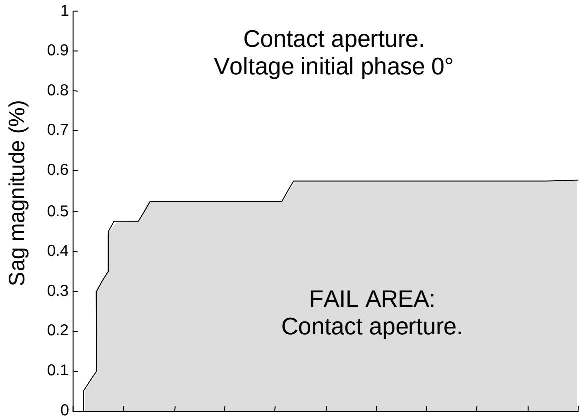


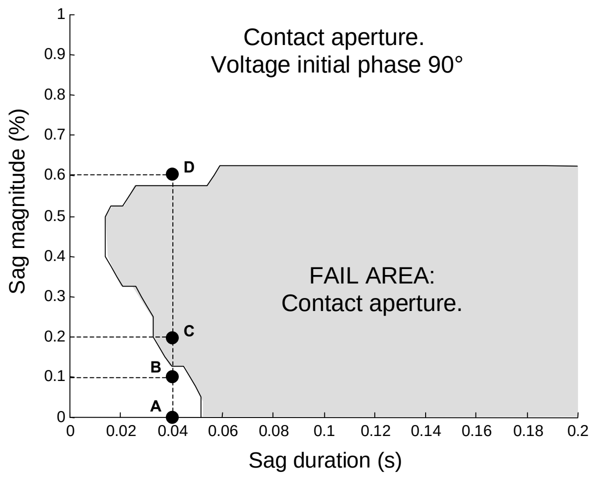


- ❑ Compare Different Manufacturers
- ❑ Purchase Suitable Piece of Equipment

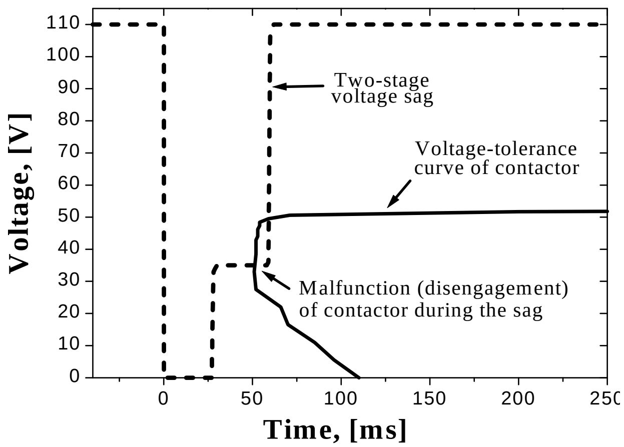
Equipment Behaviour: Results

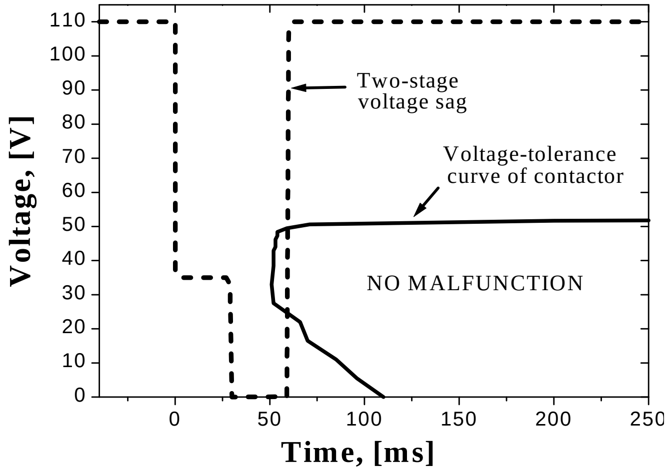
AC Contactors: Point on Wave of Dip Initiation





AC Contactors: Dip Shape (Multi-stage Dips)

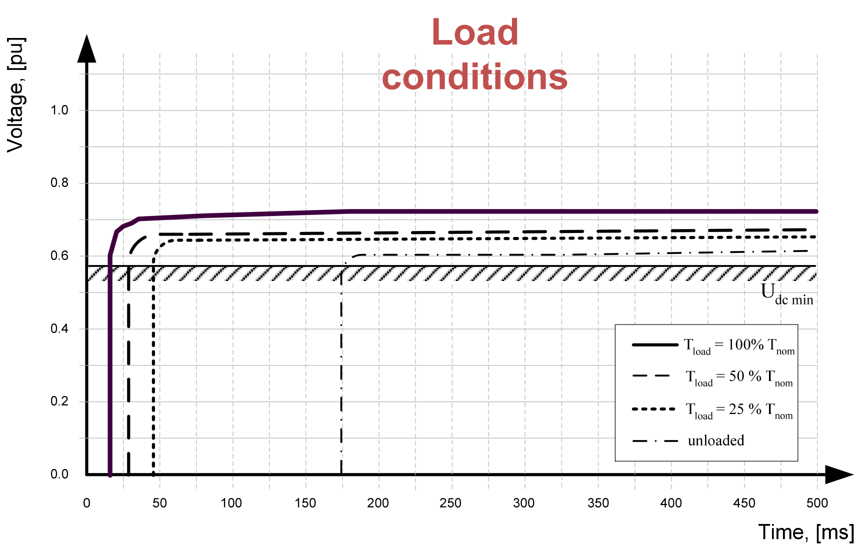


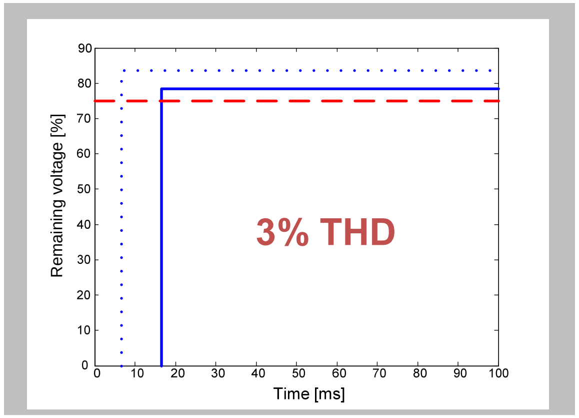


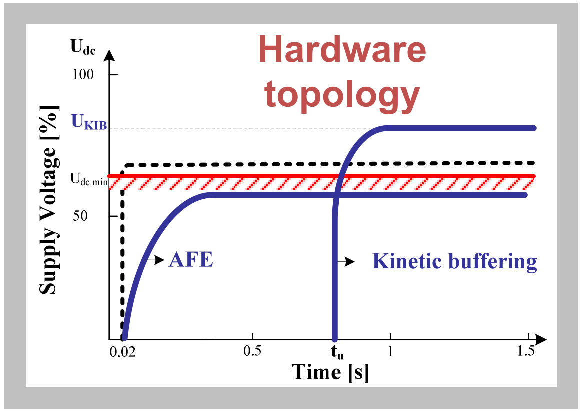
Equipment Behaviour: Results

Parameters Impacting the Behaviour

Adjustable speed drives (AC)







Equipment Behaviour: Results

Parameters impacting the behaviour

- Both manufacturers and end-users should understand the actual impact of dip events on different types equipment
- The design of new equipment should be modified in accordance with this understanding
- Testing: What Parameters to Test Against?
- Research questions:
  - Reclosing of protective devices and multi-stage dips
  - Influence of pre-dip voltage supply conditions

Assessment of Process Immunity

- Gathering information on dip immunity of a wide variety of processes:
  - Difficult: Not enough information available
  - Each process considered as unique
- Formulation of a general framework
- Useful inputs
  - Electrical engineers do not have all the knowledge
  - Identification of critical devices: “trivial” devices often forgotten (sensors, ice-cube relays, control equipment…)
  - Two general types of processes: “slow” and “fast” →

Process Immunity Time Concept

- Process parameters need to be kept within specs – equipment is just a tool to do so!
- List ALL equipment (actuators, controls, protection)
- How fast do process parameters vary?
  - Electrical engineers, process & process control engineers, instrumentation engineers, ... need to join forces
  - Interruptions – easier to test & worst case
  - Past disturbances records, simulations

Process Immunity Time Concept

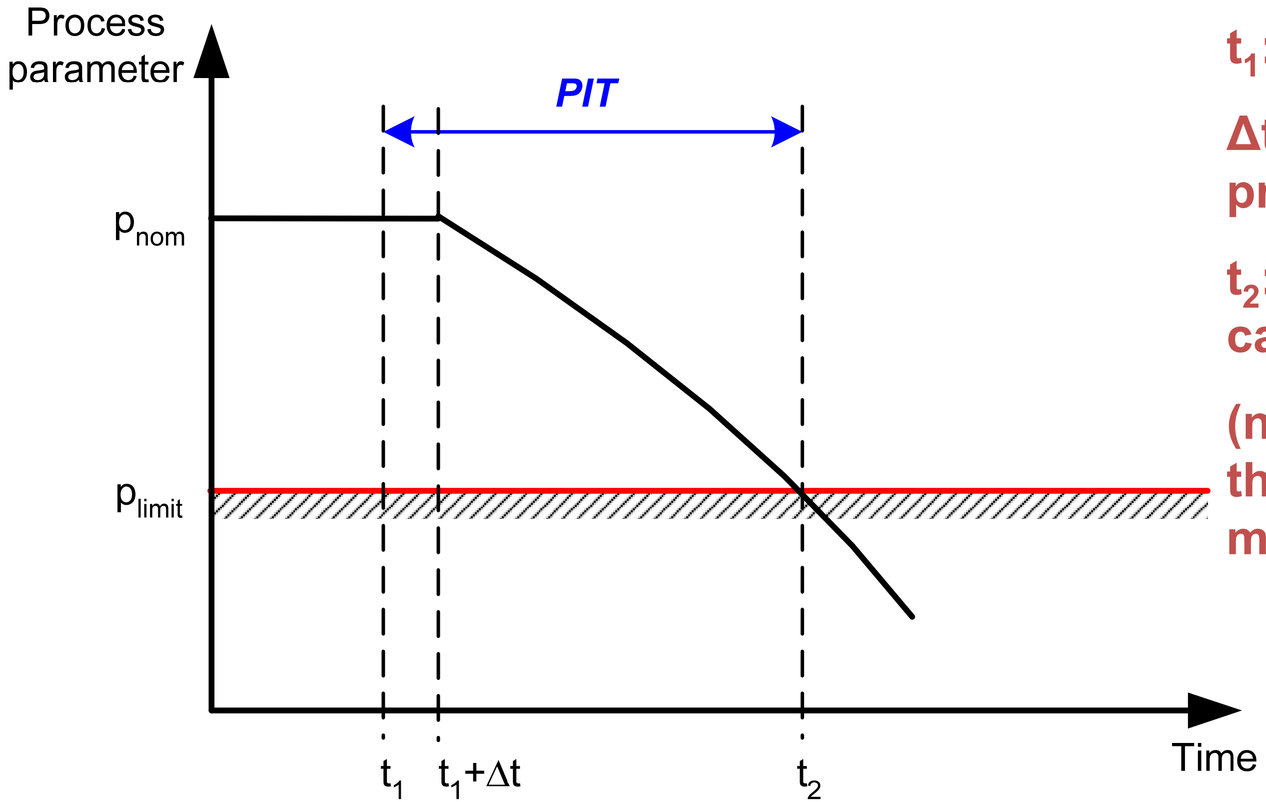
Procedure:

1. List all equipment
2. Split the process in functional units or parts
3. Link relevant equipment to specific process parameters
4. Establish the nominal, upper and lower limits for each process parameter
5. Determine PIT (e.g. against interruptions)
6. Identification of critical process parameters and critical equipment

Process Immunity Time Concept

Process Immunity Time

– Related to equipment controlling/maintaining a parameter



t_1: interruption starts

Δt: "dead time" of the process/equipment

t_2: process parameter cannot be maintained

(normal operation of the process cannot be maintained)

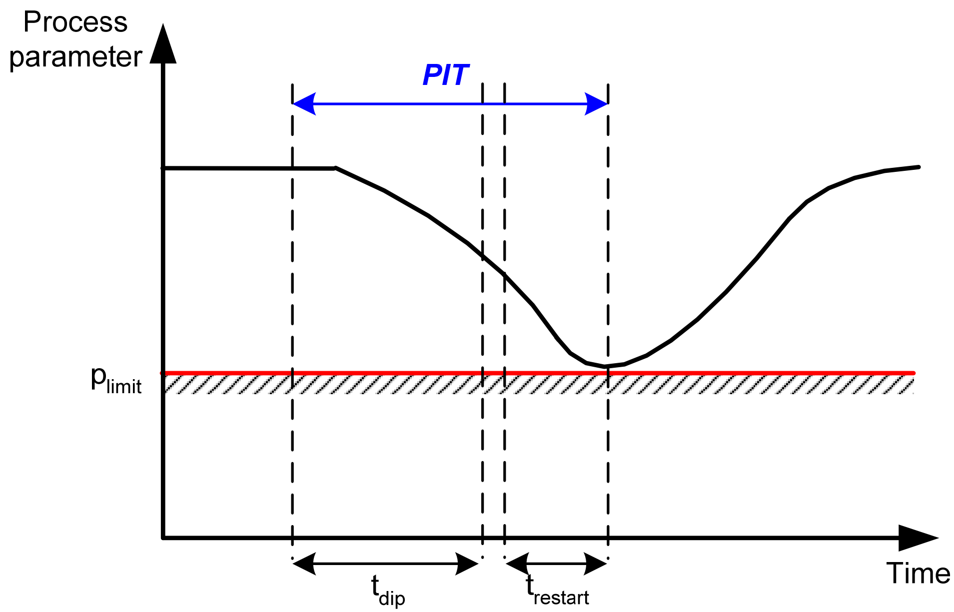
$PIT = t_2 - t_1$

PIT Example: Reactor

LEVEL 1	LEVEL 2	LEVEL 3	Process parameter	PIT	Priority	Action
Reactor						
	Cooling					
		DOL IM 1 (water)	Reactor cooling water temp	5s	4	Restart 1
		Oil pump	Oil pressure	1,5s	2	Crucial
		DOL IM 2 – fan	Cooling of the water circuit	3min	7	Restart 3
	Reaction					
		DOL IM 3 (feed)	Flow rate	30s	6	Restart 2
		ASD 1 (mixer)	Reaction time	6s	5	Restart
		ASD 2 (air)	% O_2	2s	3	Mitigate
	Control					
		Temperature sensor	Reactor temperature	1 h	8	
		Oxygen measurement	% O_2	1s	1	Mitigate
		PLC with UPS		1 h	8	

How to Use PIT to Analyze/Improve Processes

- "High" PIT (PIT > typical dip duration):
  - Equipment mitigation not critical
  - Can be stopped (at dip detection) and restarted



e.g. DOL IM3:
PIT = 30 s

Reaction			
	DOL IM 3 (feed)	Flow rate	30s

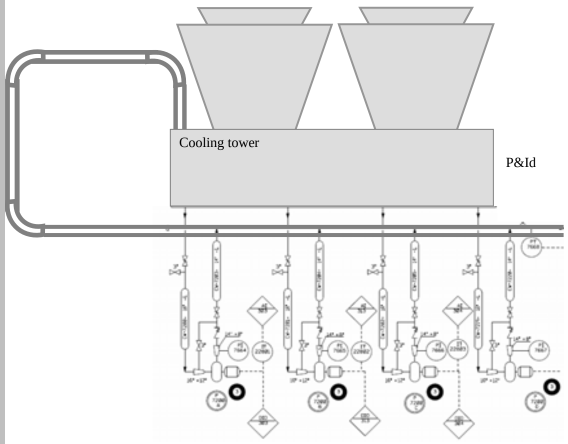
How to Use PIT to Analyze/Improve Processes

- "Low" PIT (PIT < typical dip duration):
  - Equipment can not be stopped and restarted
  - Ride-through is essential
  - Knowledge of individual equipment behaviour under dip conditions is required
  - Interaction with manufactures required
    - Other piece of equipment
    - Install more buffer in the process?

e.g. Oxigen measurement: PIT = 1 s

Oxygen measurement	% O_2	1s

PIT Example: Cooling Tower



LEVEL 1	LEVEL 2	LEVEL 3	Process parameter	PIT	Priority	Action
Cooling system						
	Cooling Tower					
		Cooling water pump	$T_{cooling\ water}$	10 s	1	Mitigate
		Air fans	$T_{cooling\ water}$	15 min	3	Restart
		Chemical dosing pumps		1 h	> 1h	Restart
	Air compressor	Air buffer	Q_{air}	30s	2	
		Internal compressor cooling control	$Q_{cooling\ water}$	3 s	1	

Conclusions

❑ Equipment Immunity

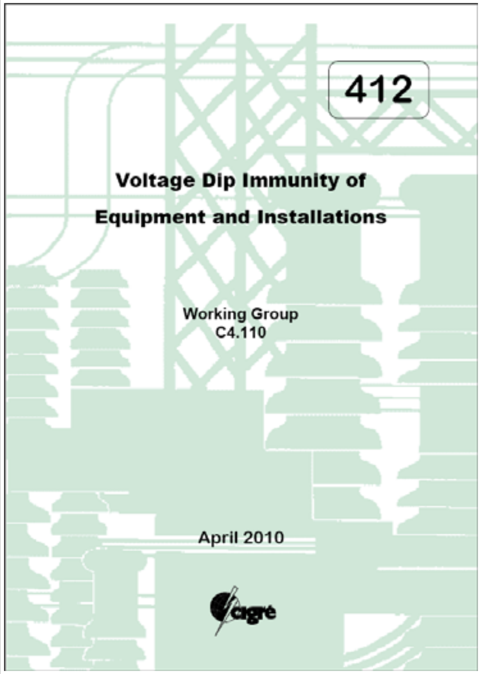
– Voltage-supply, equipment-specific & non-electric factors/parameters of influence

– Wide range in equipment responses & behaviour!

❑ Processes

– Definition of the PIT concept

- All equipment should be considered
- Engineers from different disciplines should join forces and learn from each other
- Ongoing activities to validate the framework



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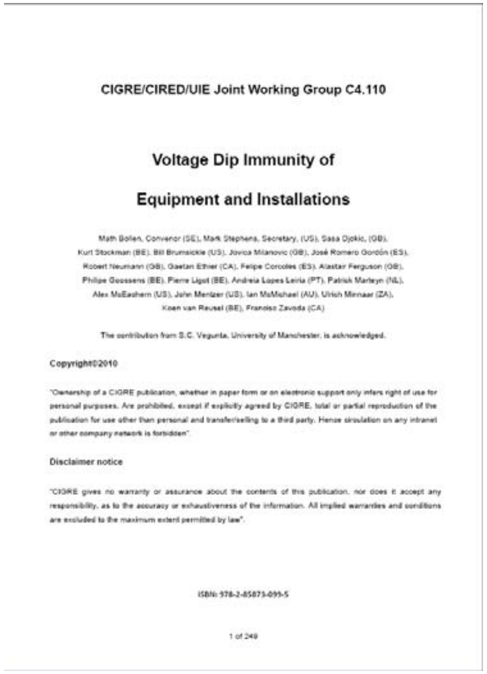

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Voltage Dip Immunity of

Equipment and Installations

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1 of 249

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