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Potential PV Penetration study in the Western Cape Work Package 3: Emerging Technologies

PV Penetration Study final workshop

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Presentation Layout

1. Introduction
2. Methodology
3. Impacts from high levels of PV penetration
4. Mitigation technologies
5. Technology evaluation
6. Results

Introduction

- **The main objective of this report is to inform technology choices to support and strengthen the distribution grid in cases when this might be needed due to large-scale uptake of rooftop photovoltaic (PV) installations.**

- **The emerging technology's ability to perform voltage control, load shifting and mitigation of intermittence will be evaluated.**

- **Provide emerging technology solutions that could remove the barriers for potential high PV penetration to stimulate investment in private and public PV installations.**

Methodology

- The relevant technologies for power quality improvement, load shifting and intermittence mitigation will be identified based on the impacts identified in Work Package 2.

- Preliminary evaluation studies will be done to deduce the cost, maturity and safety of the identified technologies.

- Technologies relevant and feasible to the impacts identified in work package 2 will also be evaluated in terms of cost.

Impacts from PV penetration

- **Voltage violations**
  - **Voltage rise**
  - **Voltage unbalance**
  - **Voltage fluctuations**
  - **Voltage flicker**
  - **High instant voltage**
  - **Voltage drop/rise on secondary**
  - **5 minute regulation violations**

Impacts from PV penetration

- Frequency violations
  - Over frequencies
  - Network frequency response capacity due to low inertia in system
- Harmonics
  - Rise in total harmonic distortion (THD)
  - Increased losses
- Reverse power flow
  - Moderate reverse power flow
  - High reverse power flow

Impacts from PV penetration

- **Equipment overload**
  - **Thermal overload**
- **Protection equipment**
  - **Tripping of protection equipment**
  - **Network protector false tripping**
  - **High short circuit contribution**
  - **Protection equipment failure to co-ordinate**
- **Low average power factor (PF)**
- **Circuit plan loading limit exceeded**
- **Impact on upstream networks**

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Mitigation technologies

	Violation → / Mitigation ↓	Voltage violations					Frequency violations		Harmonics	Reverse power flow		Protection equipment		Other				
		(1) Voltage rise	(2) Voltage fluctuations	(3) Voltage flicker	(4) Voltage unbalance	(5) Malfunction operation of voltage regulation equipment	(6) Over frequencies	(7) Network frequency response capacity due to low inertia	(8) Rise in total harmonic distortion (THD)	(9) Reverse power flows in distribution system	(10) Additional power flows in transmission system	(11) Tripping of protection equipment	(12) High short circuit contribution	(13) Protection equipment failure to co-ordinate	(14) Low average power factor	(15) Equipment thermal overload	(16) Circuit plan loading limit exceeded	(17) Increased losses
DSO-side solutions	Network strengthening	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Network reconfiguration	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Distribution storage	✓	✓				✓	✓		✓	✓					✓	✓	✓
	Advanced voltage control for HV/MV transformers	✓				✓												
	OLTC for MV/LV transformers	✓	✓															
	SVR	✓	✓															
	SVC	✓	✓	✓					✓						✓			✓
	TCSC												✓			✓	✓	✓
	TCVL	✓																
	SSSC												✓			✓	✓	✓
	IPC												✓			✓	✓	✓
	STATCOM	✓	✓	✓					✓						✓			
	UPFC	✓	✓	✓					✓				✓		✓	✓	✓	✓
	IPFC	✓	✓	✓												✓	✓	✓
Prosumer-side solutions	Active power control or curtailment	✓	✓	✓	✓				✓	✓	✓					✓	✓	✓
	Prosumer Storage	✓	✓	✓	✓				✓	✓	✓					✓	✓	✓
	Reactive power control	✓	✓		✓										✓			
	Load shifting control	✓			✓					✓	✓					✓	✓	✓

Mitigation technologies - FACTS

Classification	Device	Functions
First generation thyristor switch control	Static var compensator (SVC)	Voltage control, transient stability, dynamic stability, damping oscillations, var compensation
	Thyristor-controlled series compensator (TCSC)	Current control, limiting short circuit current, transient stability, dynamic stability, active and reactive power flow control
	Thyristor-controlled voltage limiter (TCVL)	Transient and dynamic voltage limit
	Thyristor-controlled phase-shifting transformer (TCPST)	Active and reactive power flow control, transient stability, dynamic stability
Second generation voltage source converter	Synchronous series compensator (SSSC)	Current control, limiting short circuit current, transient stability, dynamic stability, active and reactive power flow control
	Interphase power controller (IPC)	Active and reactive power flow control, limiting short circuit current
	Static synchronous compensator (STATCOM)	Voltage control, VAR compensation, transient stability, dynamic stability, damping oscillations
	Unified power flow controller (UPFC)	Voltage control, active and reactive power flow control, transient stability, dynamic stability, limiting short circuit current, damping oscillations, VAR compensation
	Interline power flow controller (IPFC)	Reactive power flow control, transient stability, dynamic stability, damping oscillations, voltage control

Evaluation criteria

Criteria	Description
Application	• Evaluates the operating violations that can be mitigated by a solution. This is already mapped in Table 4.
Technology readiness	• Evaluates the maturity level of the proposed solutions for mitigating the impacts of high PV penetration. • For this criterion, solution can either be commercially available, successful in pilot grid demonstrations, successful in laboratory or in early research stage.
Applicability within existing regulation	• Evaluates if different solutions can be implemented within existing regulation or if different solutions require new regulatory developments. • For this criterion, "yes" indicates that the solution is applicable within existing regulation while "no" indicates that the solution require new regulatory developments.
Investment cost	• Evaluates the investment cost required for different solutions. • For this criterion, solution can either have low, average or high investment cost.

Evaluation results

	Solution	Application	Technology readiness	Applicable within existing regulations	Investment cost
DSO-side solutions	Network strengthening	(1), (2), (3), (4), (5), (8), (9), (10), (11), (12), (13), (14), (15), (16), (17)	Commercial	Yes	High cost
	Network reconfiguration	(1), (2), (3), (4), (5), (8), (9), (10), (11), (12), (13), (14), (15), (16), (17)	Commercial	Yes	Low cost
	Distribution storage	(1), (2), (6), (7), (9), (10), (15), (16), (17)	Commercial	Yes	High cost
	Advanced voltage control for HV/MV transformers	(1), (5)	Demo	Yes	Average cost
	OLTC for MV/LV transformers	(1), (2)	Demo	Yes	High cost
	SVR	(1), (2)	Commercial	Yes	Average cost
	SVC	(1), (2), (3), (8), (14)	Commercial	Yes	High cost
	TCSC	(12), (15), (16), (17)	Commercial	Yes	High cost
	TCVL	(1)	Commercial	Yes	High cost
	SSSC	(12), (15), (16), (17)	Commercial	Yes	High cost
	IPC	(12), (15), (16), (17)	Commercial	Yes	High cost
	STATCOM	(1), (2), (3), (8), (14)	Commercial	Yes	High cost
	UPFC	(1), (2), (3), (12), (14), (15), (16), (17)	Commercial	Yes	High cost
	IPFC	(1), (2), (3), (15), (16), (17)	Commercial	Yes	High cost

Evaluation results

	Solution	Application	Technology readiness	Applicable within existing regulations	Investment cost
Prosumer-side solutions	Active power control or curtailment	(1), (2), (3), (4), (8), (9), (10), (15), (16), (17)	Commercial	No	Low cost
	Prosumer Storage	(1), (2), (3), (4), (8), (9), (10), (15), (16), (17)	Commercial	Yes	High cost
	Reactive power control by inverter	(1), (2), (4), (14)	Commercial	No	Low cost
	Load shifting	(1), (4), (9), (10), (15), (16), (17)	Commercial	Yes	High cost

Conclusions and recommendations

- Active and reactive power control by the inverter
  - Incentives to encourage prosumers to consider these solutions will most probably result in the best value for money.

- Following on the limitations presented in WP2, the emerging technologies would have to be investigated further, modelled and costed for the various environments before a more informed decisions could be made regarding the implementation.

- Higher resolution temporal network data is required to model these technologies effectively so that the cost as well as the impact on the quality of supply can be evaluated.