

# **STATCOM with Energy Storage to Smooth out Intermittent Power Output of Wind Farms**

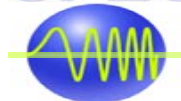
Mesut Baran   Sercan Teleke   Subhashish Bhattacharya   Alex Huang  
Loren Anderson (BPA)   Stanley Atcitty (SNL)   Imre Gyuk (DOE)

**Sponsors: BPA & DOE Energy Storage Program**

Funded in part by the Energy Storage Systems Program of the U.S.  
Department Of Energy (DOE/ESS) through Sandia National  
Laboratories (SNL).

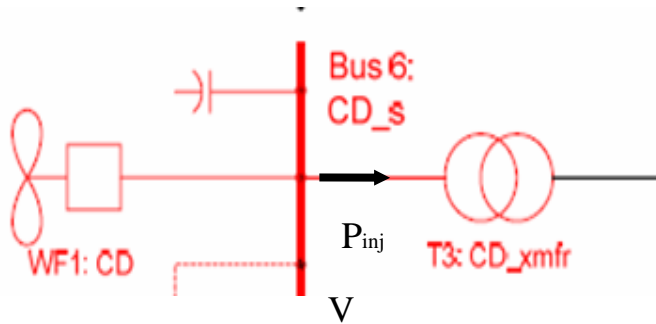
Sandia is a multi-program laboratory operated by Sandia  
Corporation, a Lockheed Martin Company, for the United  
States Department of Energy's National Nuclear Security  
Administration under contract DE-AC04-94AL85000.

**SPEC**

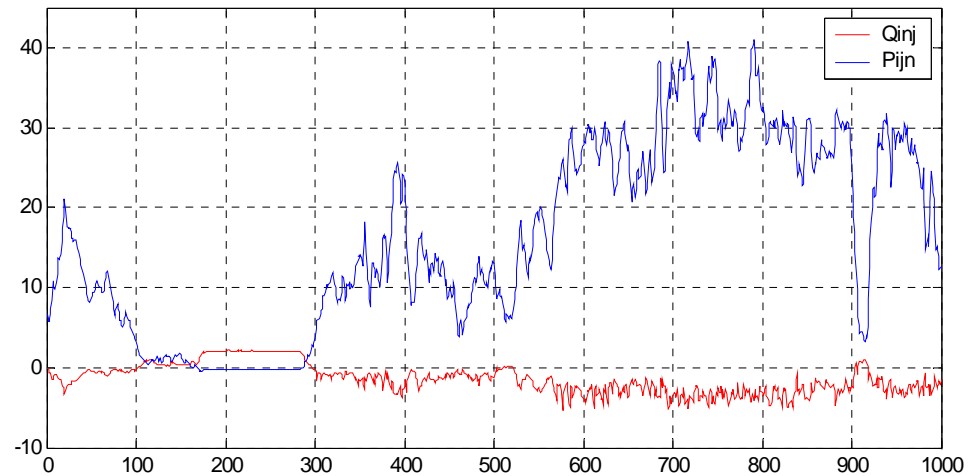


**NC STATE UNIVERSITY**

# Wind Farm Power

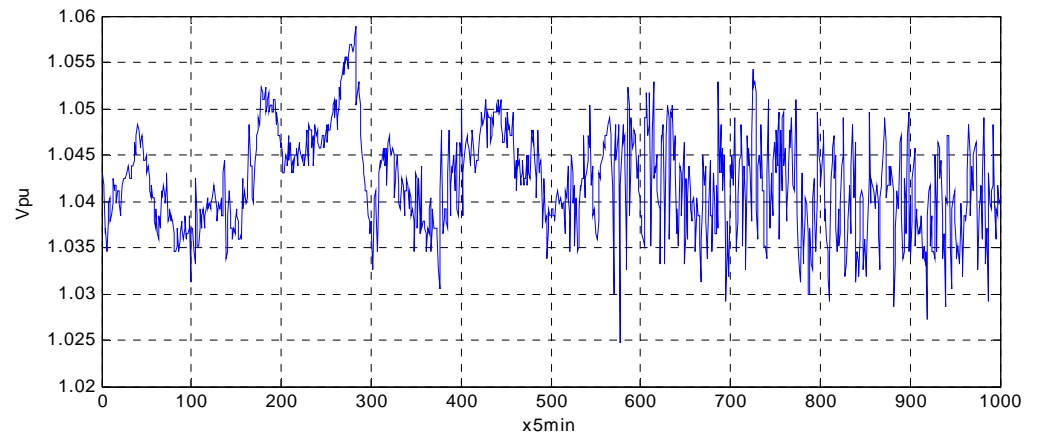


Wind Power



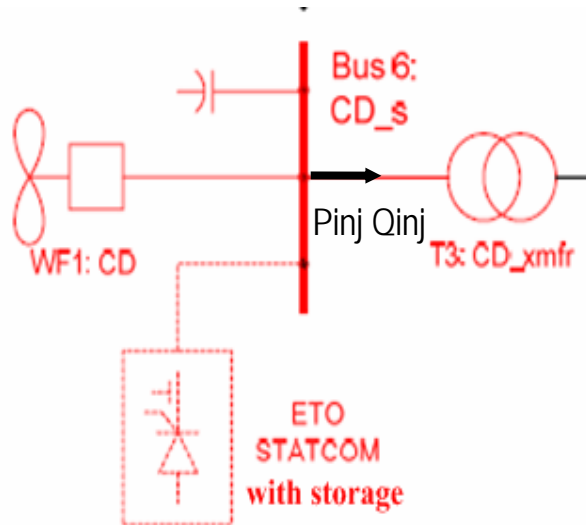
## Challenges:

- Variation of Power
- Q support

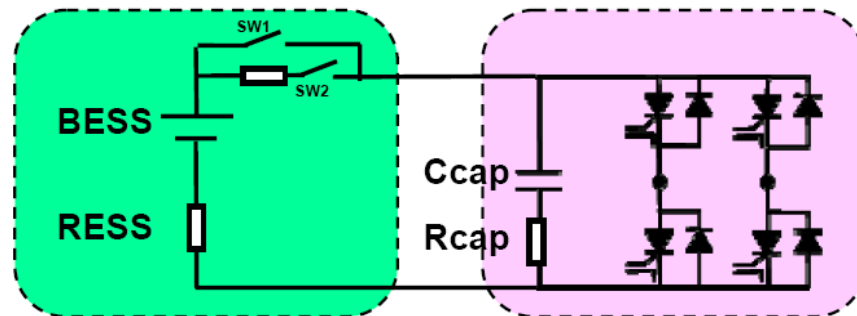


**Need to smooth both  $P_{inj}$  and V**

# Proposed Solution: STATCOM with BESS



## BESS Integration

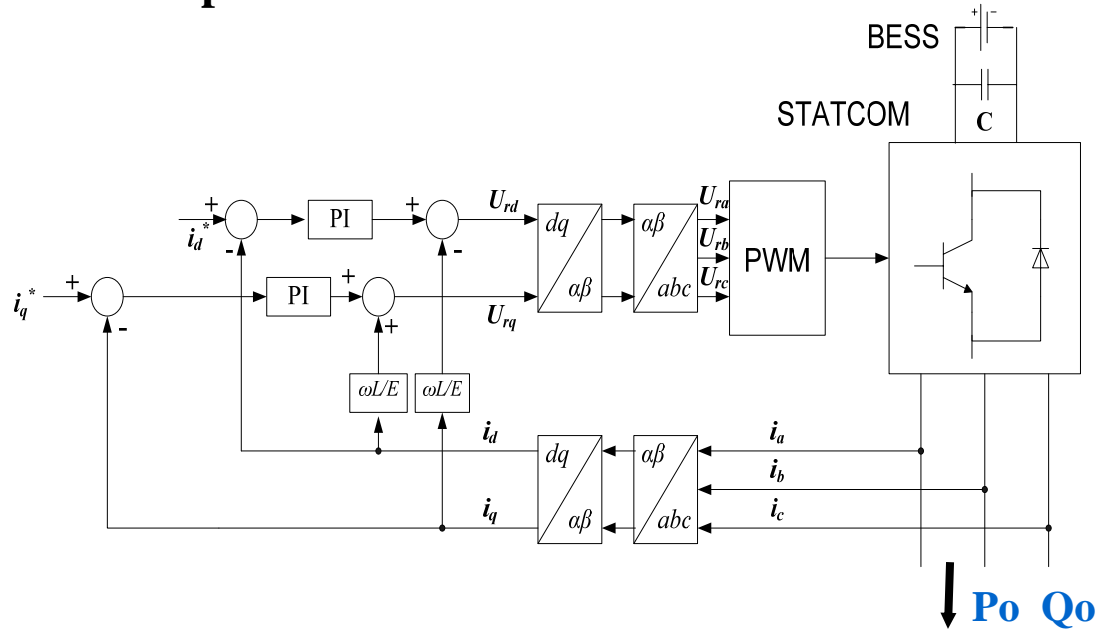


STATCOM BESS -> control of both  $P_{inj}$  &  $Q_{inj}$

**STATCOM BESS can smooth both  $P_{inj}$  and V**

# Control of STATCOM-BESS

## Inner current control loop of STATCOM



## Decoupled control

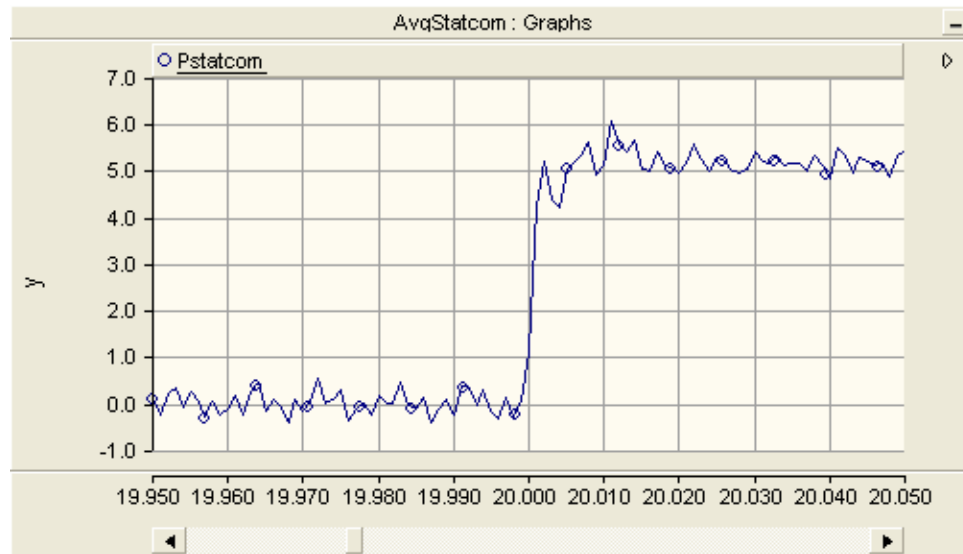
$$P_o = \frac{3}{2} U_d i_d$$

$i_d$  controls  $P_o$

$$Q_o = \frac{3}{2} U_d i_q$$

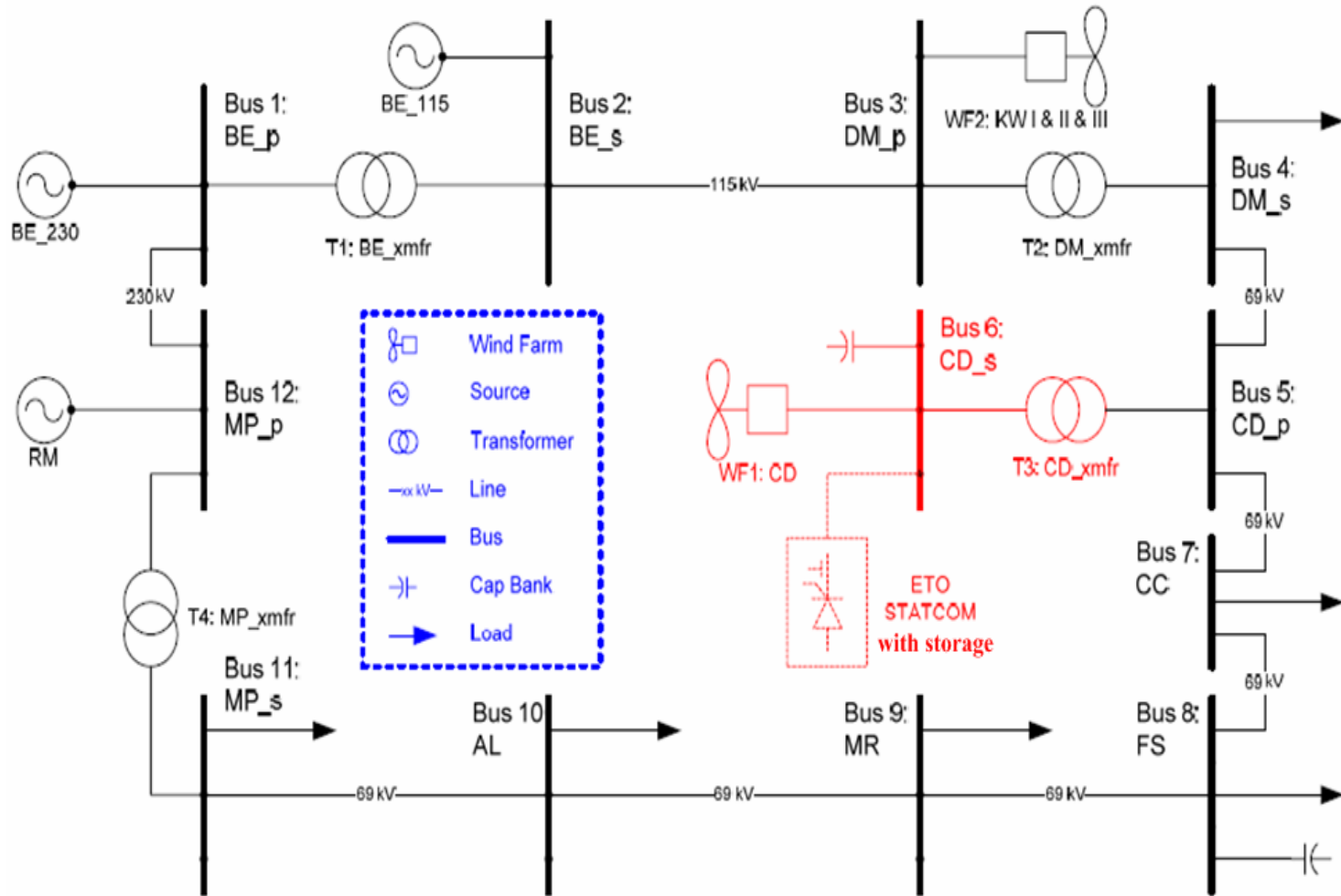
$i_q$  controls  $Q_o$

# Decoupled control test



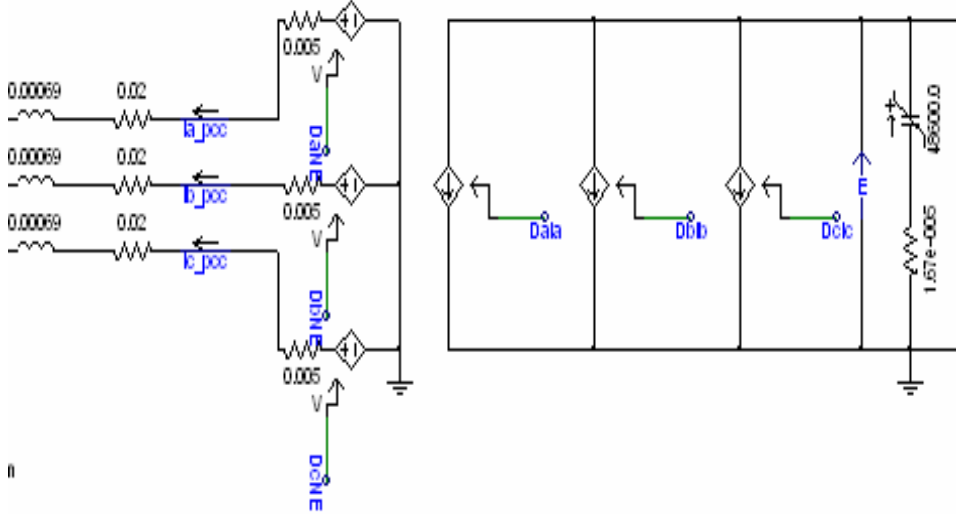
STATCOM-ES response to a change in  $I_d$  setting

# Case Study

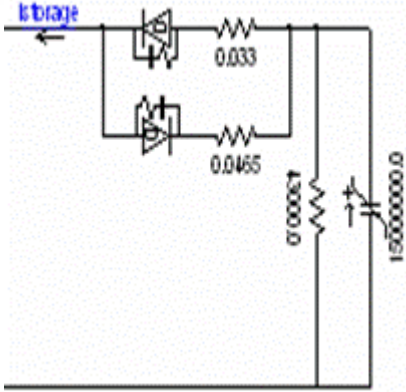


# STATCOM BESS Simulation

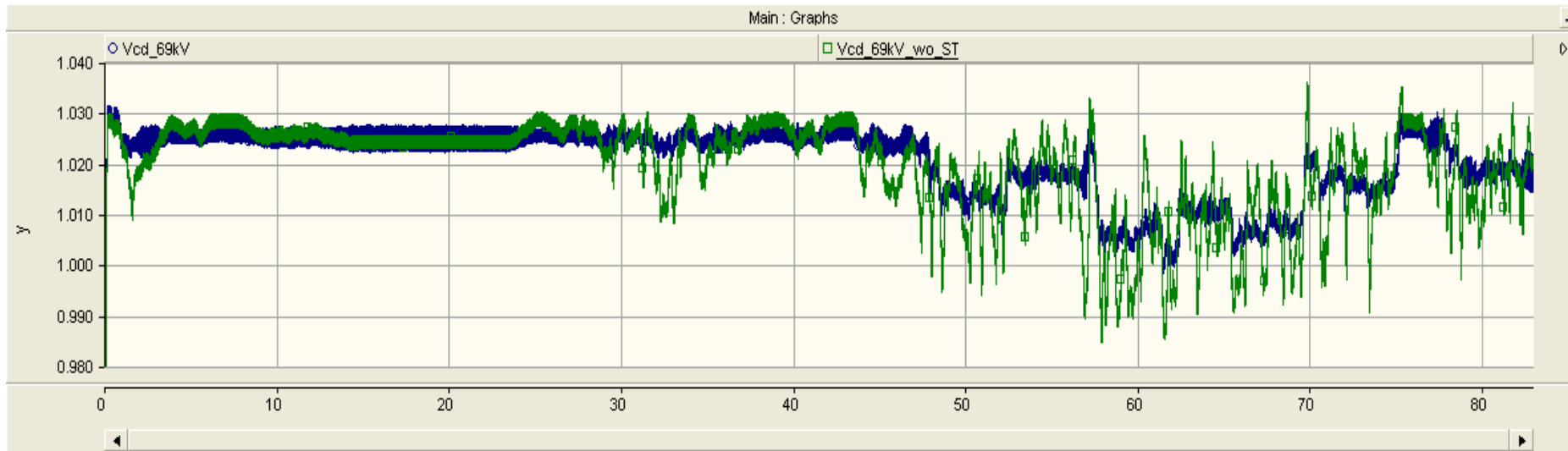
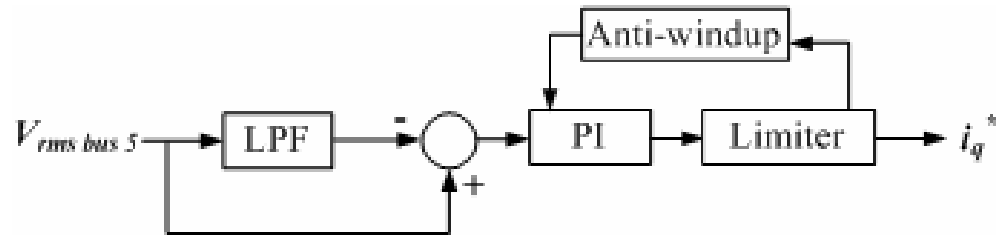
STATCOM Average model



BESS equivalent circuit



# Smoothing Voltage



**Voltage Smoothing by STATCOM with 10 MWh BESS**



# Smoothing Pout

## Challenge: BESS

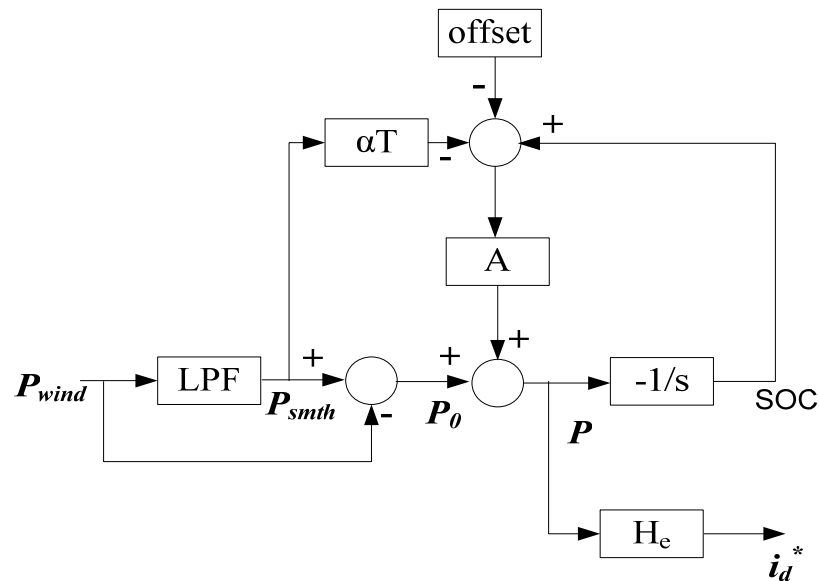
**State of Charge (SOC) ~ Energy Stored in BESS**

**need to keep  $30 < \text{SOC} < 100 \%$**

**SOC ~ BESS voltage (non-linear)**

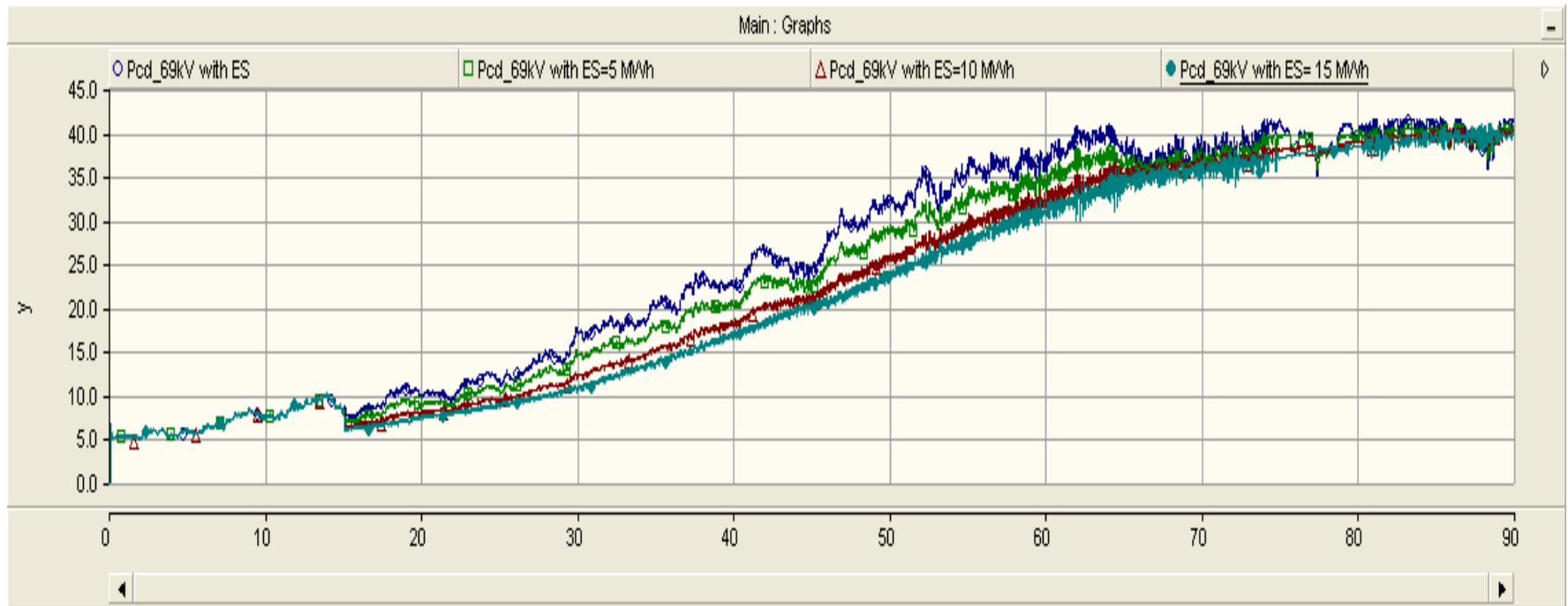
# Approach: Washout Filter with SOC Feedback

Proposed by K.Yoshimoto, T.Nanahara, G.Koshimizu



- + SOC constraint is satisfied & Vdc is kept within limits
- + Good for smoothing short-term fluctuations

# Smoothing Short-term (10 min ) power variations



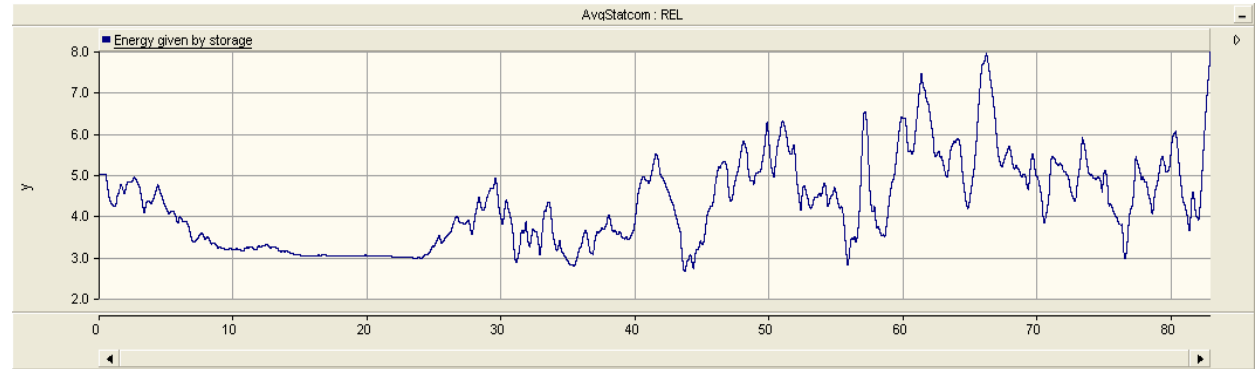
Smoothing provided by the washout filter based control  
(blue: wind farm output, green: 5 MWh, red: 10 MWh, mag.: 15 MWh).

→ 10 MWh BESS provides effective smoothing

# STATCOM BESS performance

BESS: 10 MWh

Remaining energy level (SOC)  
of the battery (MWh).



DC link voltage (kV)

