Vindkraftsforskning i fokus 2017

Larger amount of wind power: What are the system integration challenges?

Chalmers – April 3-4, 2017

by Lennart Söder
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Three challenges in a power system with large amounts of solar and wind power

C1: Keep the **continuous balance**

C2: Handle situations with **small** amounts of variable production.

C3: Handle situations with **large** amounts of variable production.

C4: Keep **voltage** in all nodes att all prod./cons. levels

Future Swedish winter challenge

C1: Keep the **continuous balance**

C2: Handle situations with **small** amounts of variable production.

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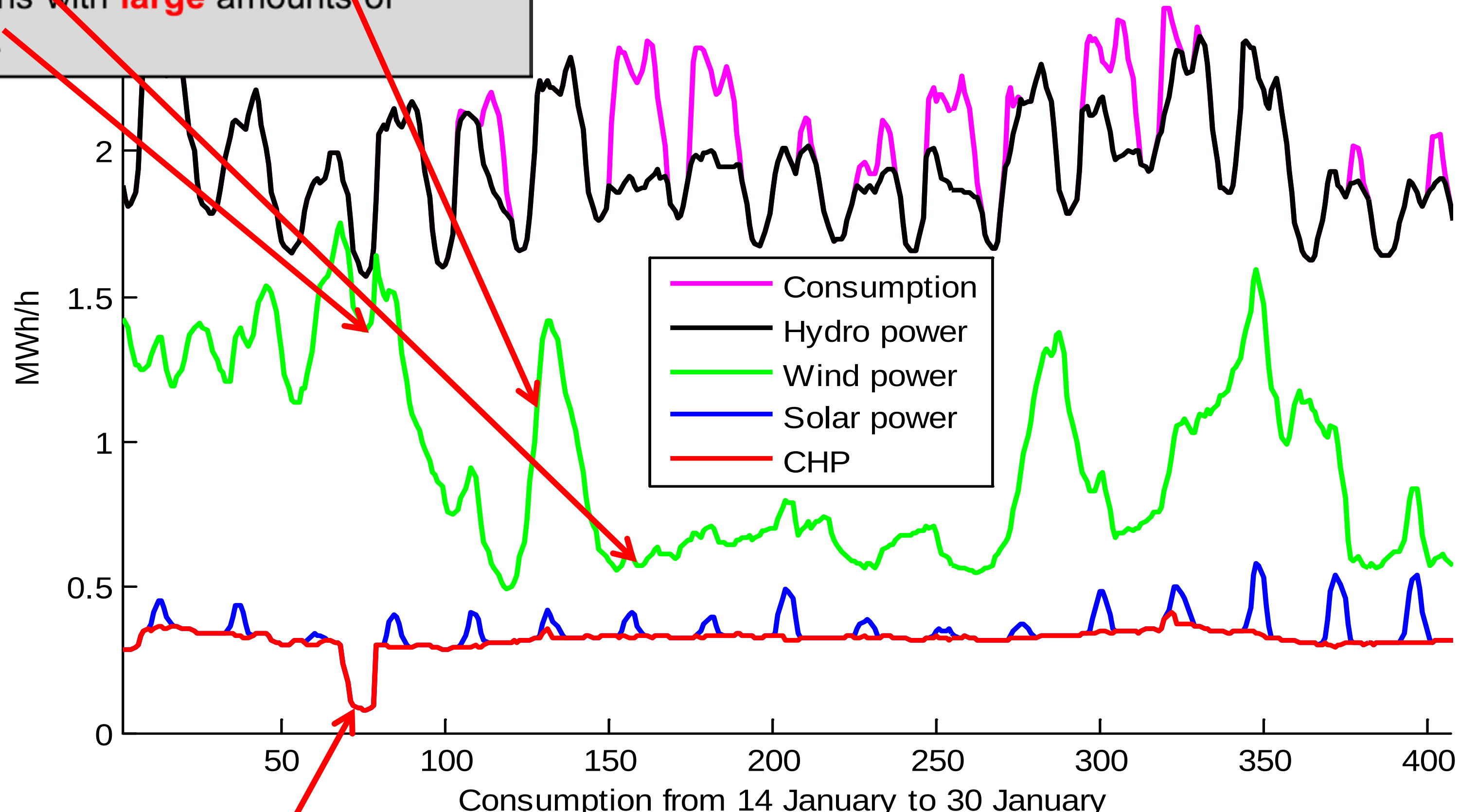

High wind ➔ decrease in CHP

Future Swedish summer challenge

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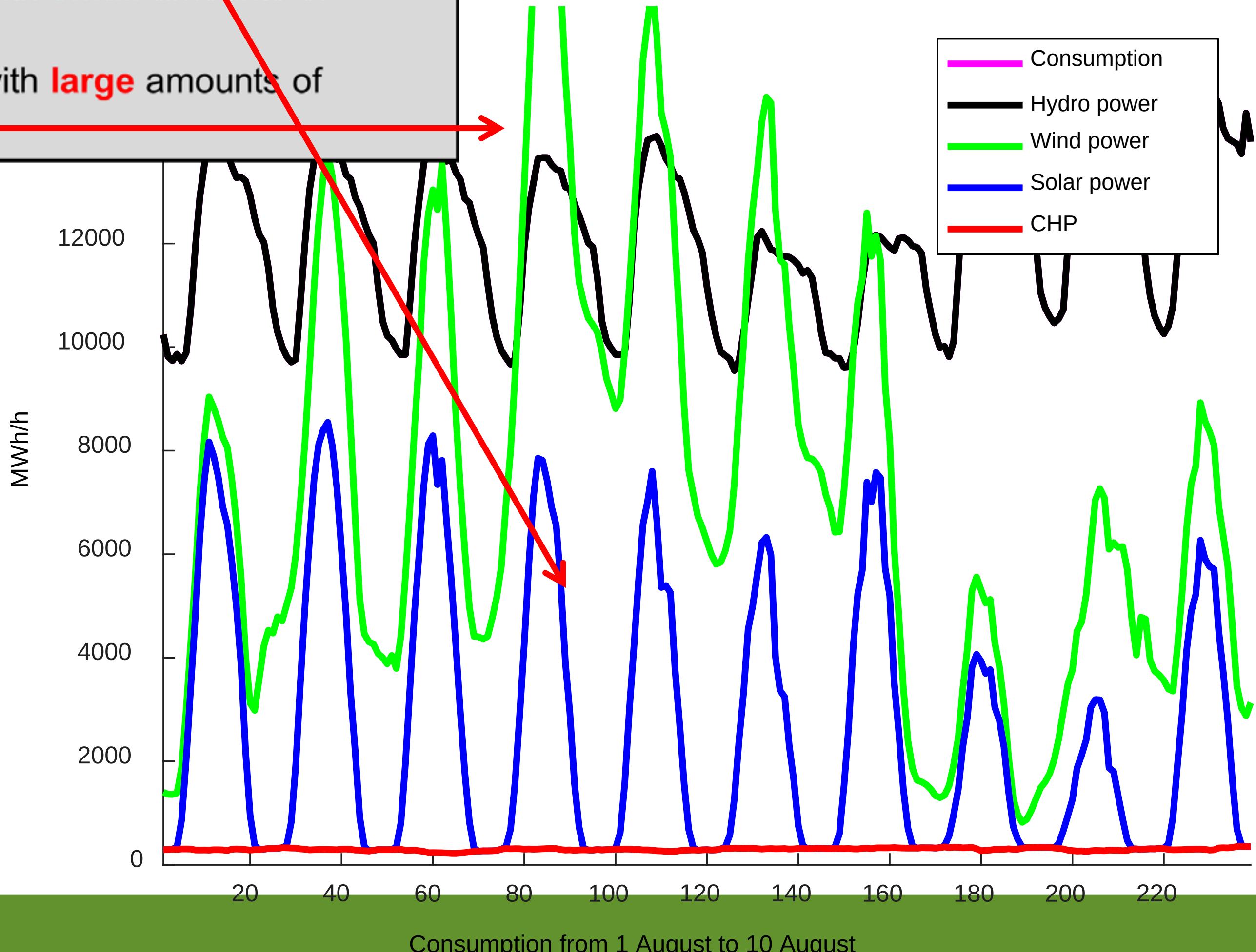
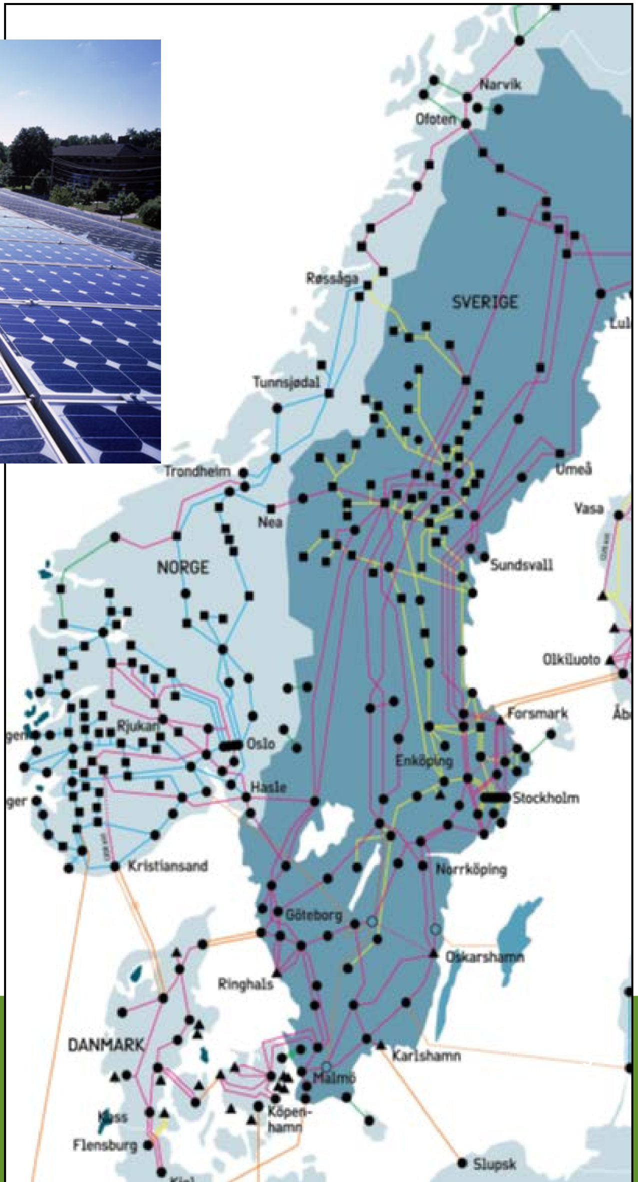


Current (170404) KTH-EPE projects-activites

Integration of Renewable Energy Sources



C2: Handle situations with small amounts of variable production.

1. **Methods for estimation of risk of capacity deficit**: **Egill Tomasson**, Svenska Kraftnät, (2015-2020).

Consider multi-area system and correlations etc

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Improved Importance Sampling for Reliability Evaluation of Composite Power Systems

Egill Tómasson, *Student Member, IEEE* and Lennart Söder, *Senior Member, IEEE*

***Abstract*—This paper presents an improved way of applying Monte Carlo simulation using the Cross-Entropy method to calculate the risk of capacity deficit of a composite power system. By applying importance sampling for load states in addition to generation and transmission states in a systematic manner, the proposed method is many orders of magnitude more efficient than crude Monte Carlo simulation and considerably more efficient than other Cross-Entropy based algorithms that apply other ways of estimating the importance sampling distributions. An effective performance metric of system states is applied in order to find optimal importance sampling distributions during pre-simulation that significantly reduces the required computational effort. Simulations, using well known IEEE reliability test systems, show that even problems that are nearly intractable using crude Monte Carlo simulation become very manageable using the proposed method.**

***Index Terms*—Monte Carlo simulation, the Cross-Entropy method, power system reliability, importance sampling, LOLP, EPNS.**

NOMENCLATURE

Indices and sets

b	Index of buses.
g	Index of generators.
l	Index of transmission lines.
i	Index of power system states.
$\mathcal{L}_b^-$	Set of transmission lines entering bus b.
$\mathcal{L}_b^+$	Set of transmission lines leaving bus b.

Variables

κ	Load excess variable.
μ	Mean of load importance sampling function.
σ	Stand. dev. of load importance sampling function.
$\mathbf{v}$	Forced outage rate reference parameter vector.
$\mathbf{X}_i$	State i of power system.
$\mathbf{X}_i^G$	$n_G \times 1$ vector of generator statuses, state i.
$\mathbf{X}_i^L$	$n_L \times 1$ vector of transmission line statuses, state i.
X_i^{LD}	Load level, state i.
p_b	Power generated at bus b.
d_b	Demand served at bus b.
f_l	Flow on transmission line l.
δ_b	Voltage angle at bus b.

Functions

$S(\cdot)$	State performance function.
$H(\cdot)$	Load shedding indicator function.
$J(\cdot)$	Amount of load shedding.
$W(\cdot)$	Likelihood ratio.
$f^{LD}(\cdot)$	PDF of load.
$c^{LD}(\cdot)$	PDF of load importance sampling function.
$\mathrm{org}(l)$	Originating bus for transmission line l.
$\mathrm{term}(l)$	Terminating bus for transmission line l.

Parameters

n_G	Number of generators.
n_B	Number of buses.
n_L	Number of transmission lines.
$\mathbf{u}$	Component forced outage rates.
$\overline{d}_b$	Demand at bus b.
$\underline{f}_l$, $\overline{f}_l$	Lower and upper transmission limits for line l.
γ_l	Negative susceptance of transmission line l.
$\mathbf{C}_G$	Generation connection matrix.
$\overline{\mathbf{G}}_G$	Installed capacity of generators.
$\overline{p}_b$	Available generation at bus b.
$\overline{\mathbf{P}}_B$	$n_B \times 1$ vector of $\overline{p}_b$.
M	A large number.
α	Pre-simulation smoothing parameter.
β	Coefficient of variation, CV.
ρ	Pre-simulation share of highest performing states.
N_{CE}	Number of samples for pre-simulation iteration.
N_β	Number of samples for main simulation, CV β.

I. INTRODUCTION

METHODS for composite reliability analysis dealing with the overall evaluation of generation and transmission configurations were not widespread prior to the 1970s [1]. Later in the 1980s, methods for multi-area evaluation of the risk of capacity deficit were developed. Reference [2] proposed a two-phased method which applied both an analytic state space decomposition phase and a Monte-Carlo simulation phase where an optimization problem was solved to minimize

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Area	2020	2025	2030
SE1	10,9 s/winter	15,7 s/winter	14,1 s/winter
SE2	363 ms/winter	695 ms/winter	596 ms/winter
SE3	23 s/winter	24,9 s/winter	24,5 s/winter
SE4	1,33 s/winter	1,65 s/winter	1,31 s/winter
FI	8,69 min/winter	6,44 min/winter	13,3 min/winter
NO1	8,28 min/winter	17,3 min/winter	17,2 min/winter
NO2	862 ms/winter	1,06 s/winter	1,10 s/winter
NO3	5,74 s/winter	8,37 s/winter	7,30 s/winter
NO4	1,20 s/winter	2,16 s/winter	1,93 s/winter
NO5	437 ms/winter	1,15 s/winter	1,06 s/winter
DK1	20,8 s/winter	55,4 s/winter	49,5 s/winter
DK2	14,6 s/winter	31,9 s/winter	29,9 s/winter

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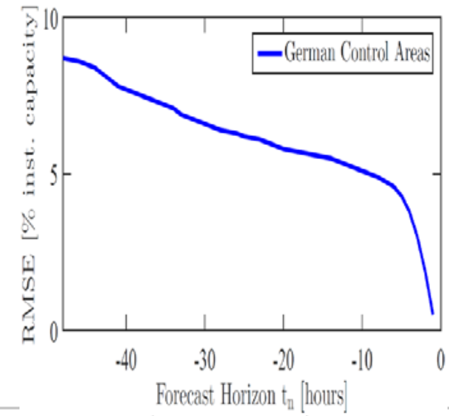
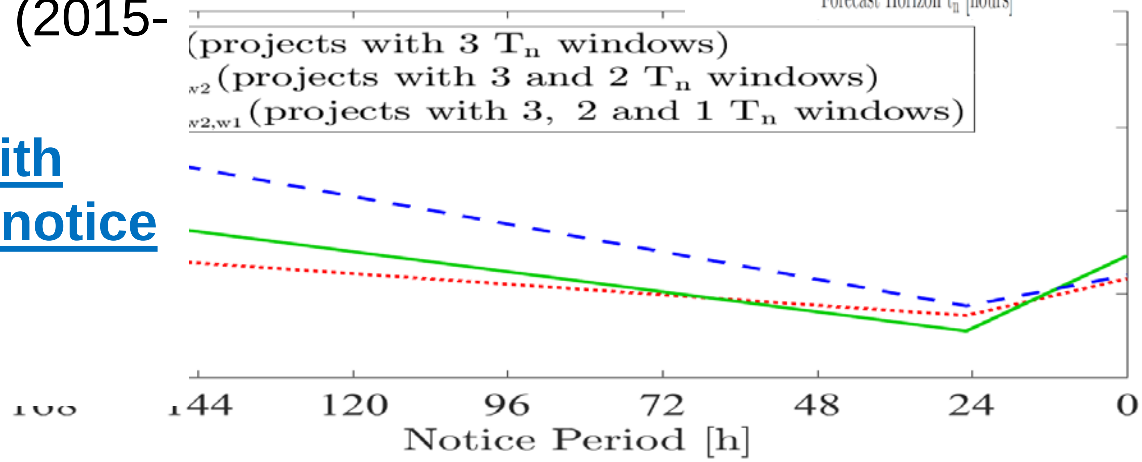
2. **The role of flexible consumers i future renewable power system**: **Lars Herre**, funded by ”Forskarskola Energisystem”, Energimyndigheten (2015-2020)



Flexible consumers with focus on impact from notice time.



C4: Keep voltage in all nodes att all prod./cons. levels

3. **VOLATILE**: Voltage Control on the transmission grid using wind power at other voltage levels, ERA-Net Smart Grids Plus (KTH+DTU), PhD student **Stefan Stankovic**, (formally 2016-2018 + other funding)

How can wind power on 20-130 kV keep the voltage on 400 kV. Cooperation with Vattenfall and DTU. (In a future with no or lower amount of nuclear power)

C1: Keep the **continuous balance**

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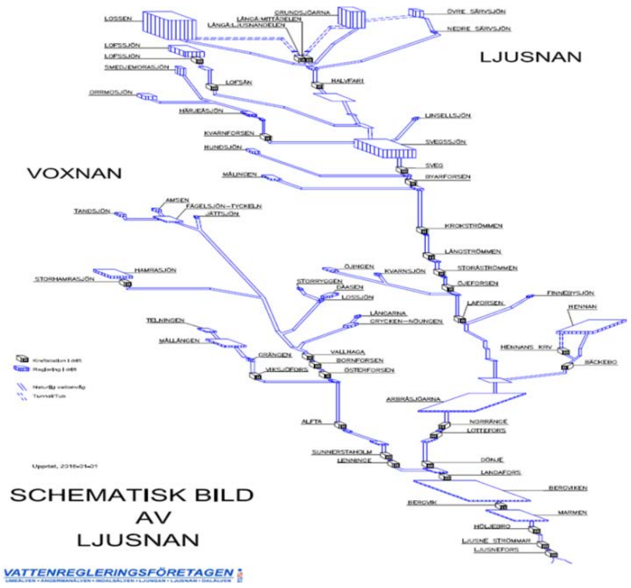
4. **Flex4RES**: Flexibility for Variable Renewable Energy Integration. Nordic Energy Research. **Lennart Söder + post doc. Mohammad Nazari**. Duration: (2015-2019)

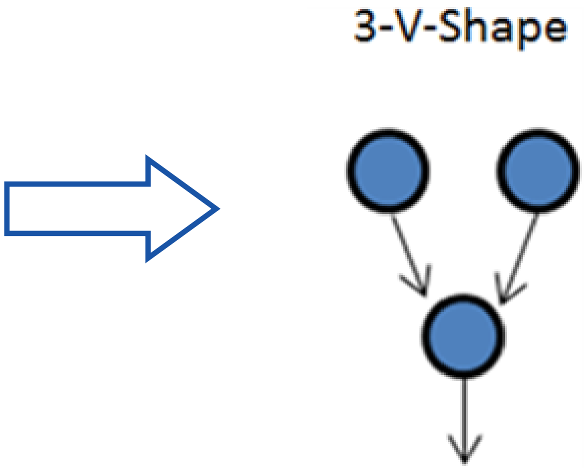
At which amount of wind power, etc, is there a need of more flexibility in the Nordic System (S+Dk+No+ Fi + EE +LV+LT) and which barriers are there.

C1: Keep the continuous balance

5. **Efficient Optimization Methods for Hydro Power Operations**: Faculty funding within a common EE-School investment. 2 PhD students, 1 with Lennart, **Daniel Risberg**, (2016-2020)

In most large scale power system models there are simplified hydro power models (e.g. 1 station for SE2). But how to make an optimal model reduction which works in a system with large volatility?





C4: Keep voltage in all nodes att all prod./cons. levels

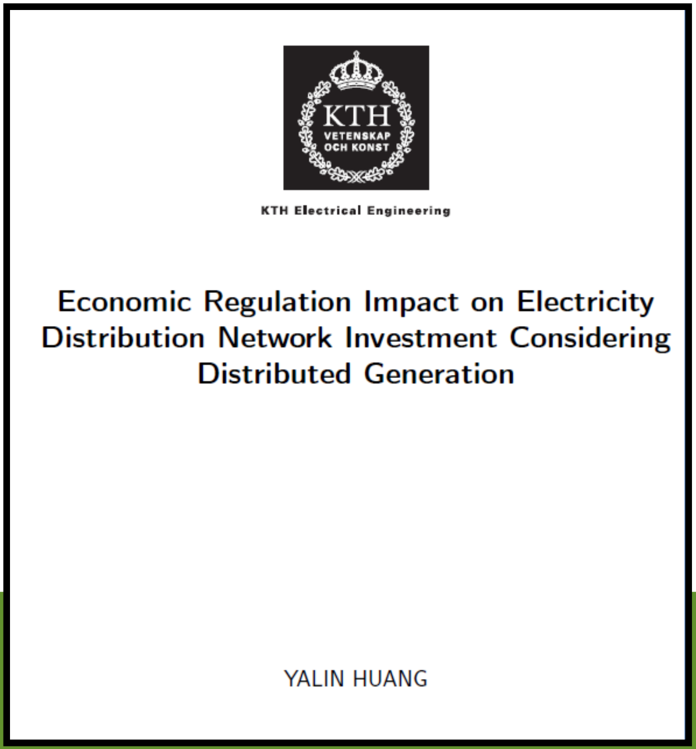
6. **Risk analys methods and their connection to grid regulation for grids with a large share of distributed generation: Yalin Huang**, Riskanalysprogrammet, (2011-2016)

Regulation impact on DSO:s decision on distribution system expansion.

PhD thesis presented March 17, 2017

Impact from:

- **Regulation**
- **Curtailments**
- **Shallow/deep payment**
- **etc**


KTH Electrical Engineering

Economic Regulation Impact on Electricity Distribution Network Investment Considering Distributed Generation

YALIN HUANG

C3: Handle situations with **large** amounts of variable production.

7. **Minimizing curtailments in power systems with high share of wind and solar power**, PhD student: **Elis Nycander**, Supervisors: Lennart Söder + Dr. Robert Eriksson, Svenska Kraftnät, **SamspEL**, (2017-2021). Energimyndigheten + Svenska Kraftnät.

Where, when, how ska should wind power be disconnected in order to minimize curtailments at high share of wind power.

Other (170403) IRES projects-activites Integration of Renewable Energy Sources

8. **SNOOPI**: **S**mart **N**etwork C**o**ntrol with C**o**ordinated **P**V **I**nfeed, SOLAR-ERA.NET (KTH+Germany). **Poria Hasanpor**, (2015-2018)

Studies of a German distribution grid (EWR-Netz in Worms, SW of Frankfurt). PV > 3*load. Strategies for how to keep voltage in the low voltage part (400/230 V)

9. **Optimal Strategies for TSO balancing**: **Martin Nilsson**, funded Svenska Kraftnät, (2015-2019)

Study consequences of different methods of keeping the frequency, e.g. changed HVDC-ramp-rates, strategies for hour shift trading, Do not do ”too much” but ”enough”.