Renewable energy balancing non-liberalized electricity markets

DNV Energy Systems

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VRE integration in electricity systems
Renewable generation in the electricity system

As part of a world-wide trend, more and more renewable energy based generation is integrated in energy supply industries (ESI).

- Large-scale RE installations feed-in into high-voltage grid
  - Need for accommodation of consequences on system & transmission level

- Small-scale RE installations feed-in into mid / low voltage grid
  - Need for accommodation of consequences on system & distribution level

Source: DNV
Flexibility in the electricity system

The electricity system disposes of several sources of flexibility that can be harnessed to meet challenges arising from renewable energy generation.

- Flexible generation assets, incl. gas-fired power plants and biomass
- Storage can provide storage services on transmission & distribution level

- Demand side management (DSM): demand is reduced to resell electricity
- Self-consumption by prosumers provides additional flexibility

Centralized generation including RE

Transmission

Decentralized RE generation

Distribution

Retail supply

Consumption

Source: DNV
VRE integration in electricity systems

Ambitious renewable-energy targets make it necessary to rethink the design of the electricity system and increase flexibility.

- IEA categorized integration of VRE into 6 different phases depending on the share of VRE in total generation
- RES progress has not been homogenous across countries (liberalized markets leading)
- No one-fits-all solution: different power sector structures, liberalization level and VRES integration challenges

Key transition challenges:

- Seasonal storage and use of synthetic fuels or hydrogen
- Longer periods of surplus or deficit of energy
- Power supply robustness during periods of high VRE generation
- Greater variability of net load and changes in power flow patterns
- Minor changes to operating patterns of the existing system
- Phase 1: VRE has no noticeable impact on the system
- Phase 2: VRE has a minor to moderate impact on system operation
- Phase 3: VRE generation determines the operation pattern of the system
- Phase 4: The system experiences periods where VRE makes up almost all generation
- Phase 5: Growing amounts of VRE surplus (days to weeks)
- Phase 6: Seasonal or inter-annual surplus or deficit of VRE supply

Source: IEA 2018
VRE in liberalized electricity systems
In centralized market VRE generated electricity typically sold in the DA market, ID is used to clear imbalances before delivery, remaining imbalances cleared via balancing markets.

Spanish example
In decentralized markets, (large-scale) renewable energy assets sell their generation output into the DA, ID is used to clear imbalances before delivery. VRE installations take full balancing responsibility.

**German example**

- **Forward Market**
- **Day Ahead Market**
- **Intraday Market**
- **Balancing Markets**

**Large-scale RE electricity - Decentralized markets**
VRE in non-liberalized electricity system
Traditionally all business areas integrated within a single company/entity, while in the SB model competition between generation plants is introduced (promoting cost efficiency) and attracting private investment (IPPs).

In vertically integrated systems, **no regulatory** tools for VRE integration exist.

In SB model **some regulatory** tools for VRE integration exist.

**Source:** DNV
Challenge RE system - Scheduling VRE and other generation

Single buyer / System Operator bears responsibility for stable delivery.

VREs have priority of dispatch and no balancing responsibility (centrally scheduled)

Balancing costs in real time are passed to the end consumer through the regulated electricity tariff

PPA with FIT

PPA take-or pay clause with flexible generators

Day -1 12:30  Day -1 14:30  Day 0 Delivery

Day-Ahead Scheduling  Adjustment  Balancing

Source: DNV
Electricity supply with single buyer – Egypt

For scheduling generation costs are calculated per power plant and the schedule is determined centrally according to actual availability of the most efficient generation plant as well as considering special PPA clauses.

**Egypt electricity system structure**

- **Generation**
  - EEHC
  - NREA
  - IPPs

- **EETC**
  - Single Buyer
  - TSO

- **Distribution companies**

- **Export & Import**
  - MV & LV consumers
  - UHV & HV consumers

Source: DNV
Generators have a PPA with the SB or are merchant plants. Scheduling process is performed by the SB, which uses the PPA prices and merchant bids to set the Day-Ahead schedule. GSO issues real-time dispatch instructions.

Peninsular Malaysia electricity system structure

- **Fuel supply (regulated)**
  - TNB-F
  - PETRONAS

- **Generation (non-regulated)**
  - TNB Gen
  - Merchant
  - IPPs

- **Grid (regulated)**
  - TNB Transmission
  - TNB Distribution

- **Retail (regulated)**
  - TNB Retail

- **NEDA** Single Buyer Grid system operator

Day-Ahead schedule

- **PPA/SLA Generators**
  - TNB generation
  - IPPs
  - Large scale solar (LSS) under a PPA

- **Merchant Generators (Non-PPA)**
  - Export PPA/SLA generators
  - Large merchant generators (part PPA/SLA, co-gen and new build ≥30 MW)

- **Price takers**
  - Co-gen
  - Small RE
  - Small franchise utility
  - A new build 100kW – 29.9MW

New Enhanced Dispatch Arrangement (NEDA)

Source: DNV
Options for balancing improvement of VRE in non-liberalized electricity system
Assumptions on SB model

- From an economic perspective, the Single Buyer model should allow optimal dispatch of VRE (holistic approach)
- The single-buyer model is often used as transitional arrangement before introduction of competitive wholesale market

However,…
- due to political motives and defined PPA preferences intervention of day-ahead schedule might lead to suboptimal resource allocation
- the SB has not a strong profit motive and therefore no incentive for innovation in flexibility options
- it is common to see delays toward liberalized electricity markets due to investment, knowledge and political reasons

Options to enhance flexibility in a SB system rely on following assumptions:
- A balancing mechanism could incentivise additional flexibility from market players besides obligations set in the PPAs
- A price signal could encourage better forecasting of new VRES capacity (e.g. in form of a balancing penalty)
- Market players are interested in signing contractual arrangements (e.g. between VRE generators and flexible generators/consumers) to improve economic performance
Status Quo: Technical balancing
SO is responsible for balancing

PPA

Balancing

Fixed power price

Conventional

Inflexible

Flexible

Renewables

Variable RE

Limited variable RE

All generators must sell their entire production to single buyer

System operator does final dispatch in real time (no balancing)

Single buyer serves suppliers and large consumers

Supplier ➔ Customer

Supplier ➔ Customer

Large Customer

Source: DNV
Balancing model 1: Commercial balancing
SO purchases balancing services

- **Fixed power price**
  - Single buyer serves suppliers and large consumers

- **PPA**
  - All generators must sell their entire production to single buyer

**Inflexible**
- Conventional

**Variable RE**
- Renewables

**Flexible**
- Single buyer serves suppliers and large consumers

- System operator does final dispatch in real time (no balancing)

**Limited variable RE**
- System operator purchases balancing services

**Customer (DSM)**
- Demand response by flexible customer

**Large Customer**
- Single buyer serves suppliers and large consumers

**Supplier**
- Customer

**System Operator**
- Single buyer serves suppliers and large consumers

**Single Buyer**
- Customer

**Source:** DNV
Balancing model 2a: VRE balancing responsible
Contract with flexible power producer

PPA with schedule + balancing responsibility

Outside centralized schedule
System operator balances and penalizes imbalance

Fixed power price
Single buyer serves suppliers and large consumers

Inflexible
Conventional

Flexible

Variable RE
Renewables

Limited variable RE

VRE balancing responsible & contract with peaking plant

System operator purchases balancing services
Demand response by flexible customer

Customer (DSM)

Supplier
Customer

Supplier
Customer

Large Customer

Source: DNV
Balancing model 2b: VRE balancing responsible
Contract with large & flexible consumer

- **PPA with schedule + balancing responsibility**
  - Inflexible Conventional
  - Flexible Renewables
  - Variable RE Renewables
  - Limited variable RE Renewables

- **Balancing**
  - Outside centralized schedule
  - System operator balances and penalizes imbalance

- **Fixed power price**
  - Single buyer serves suppliers and large consumers

- **System Operator**
  - Purchases balancing services

- **Single Buyer**
  - VRE balancing responsible & contract with industrial consumer
  - Demand response by flexible customer

Source: DNV
Balancing model 2c: VRE balancing responsible
Virtual power plant

- **Conventional**
  - Inflexible
  - Flexible
  - Virtual power plant

- **Renewables**
  - Variable RE
  - Limited variable RE

- **Variable RE & Conventional & Customer** create virtual power plant to cover balance responsibility and provide balancing.

- **System Operator** balances and penalizes imbalance.

- **Single Buyer** serves suppliers and large consumers.

- **Fixed power price**

- **PPA with schedule + balancing responsibility**

- **Source:** DNV
Thank you for your attention

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