Virtual Power Plant Control Center and its Impact on Power System Control Architecture

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- **Virtual Power Plants VPP**
- **Existing solutions** /comercial/case studies
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Motivation/challenges

- DG/RES increase, including small size sources at LV and MV network
- Volume of trading is increasing
- Different market and services emerging
- Uncertainty, Variability
- Tendency to include customer generation/DR capabilities ⇨Need to aggregate resources, which numbers and variety are increasing
- Potential exist: VPP market 1.1 BUSD (2014), 5.3 BUSD (2022) (Navigant forecast)

Problem is three fold

- **How to integrate DER in the power system**
  - Dependent on type, size, location, volt. level, etc.
  - Technical problem⇨ Connection rules, at physical level
- **How to integrate DER in the market**
  - Electricity, capacity, AS markets (reserves, P, Q, restoration service,…)
  - Aggregation, Regulation
- **How to integrate DER in existing architecture**

DER aggregation, How?

- **Terminology: VPP, µG,…not settled yet**
- **DG resources: classic and RES, numerous…**
- **Different situation at different countries**
- **Relation with Smart Grid?**
- **DER=DG+DR+DSTO**
- **Scope, structure** (technical, market side)
- **VPP types,** dominant:
  - Supply-side VPP's (Europe)
  - Demand-side VPP's (USA)
  - Mixed Asset VPP's

DER Management Approaches

1. The internet model (VPP, Virtual utilities, Power Hub)

2. Active networks (from **distribution**, with DG/RES, Siemens, SG side, ADMS), ability to control V, flow,…

3. Micro grids

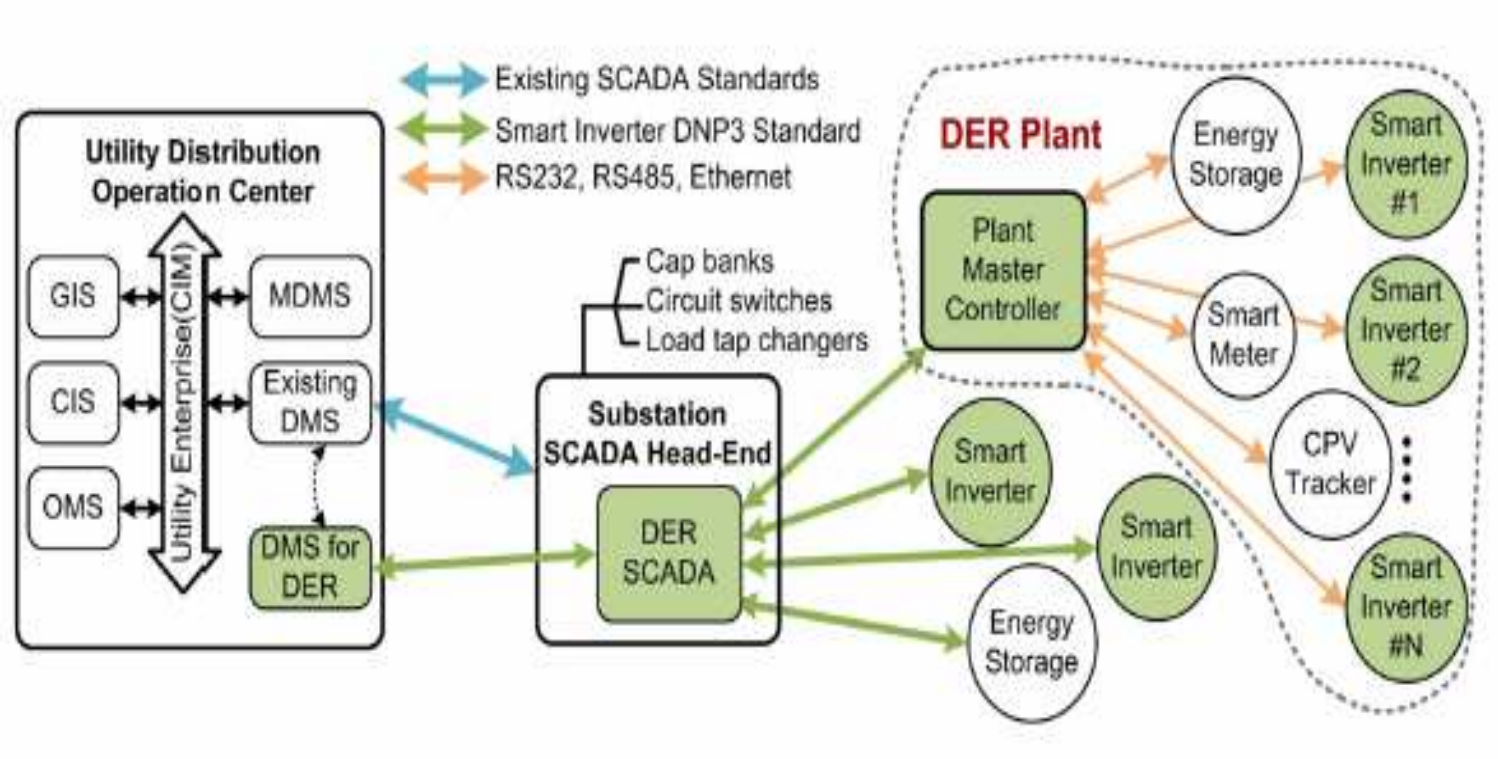
- refers to the concept of single el. power subsystem associated with a small number of DER, both renewable and/or conventional, together with a cluster of loads (Hindawi)
- **µG** is a sustainable and reliable energy system comprising off a number of different energy sources capable of seamlessly operating on or off the provincial grid. (OSI soft conf)

VPP definitions

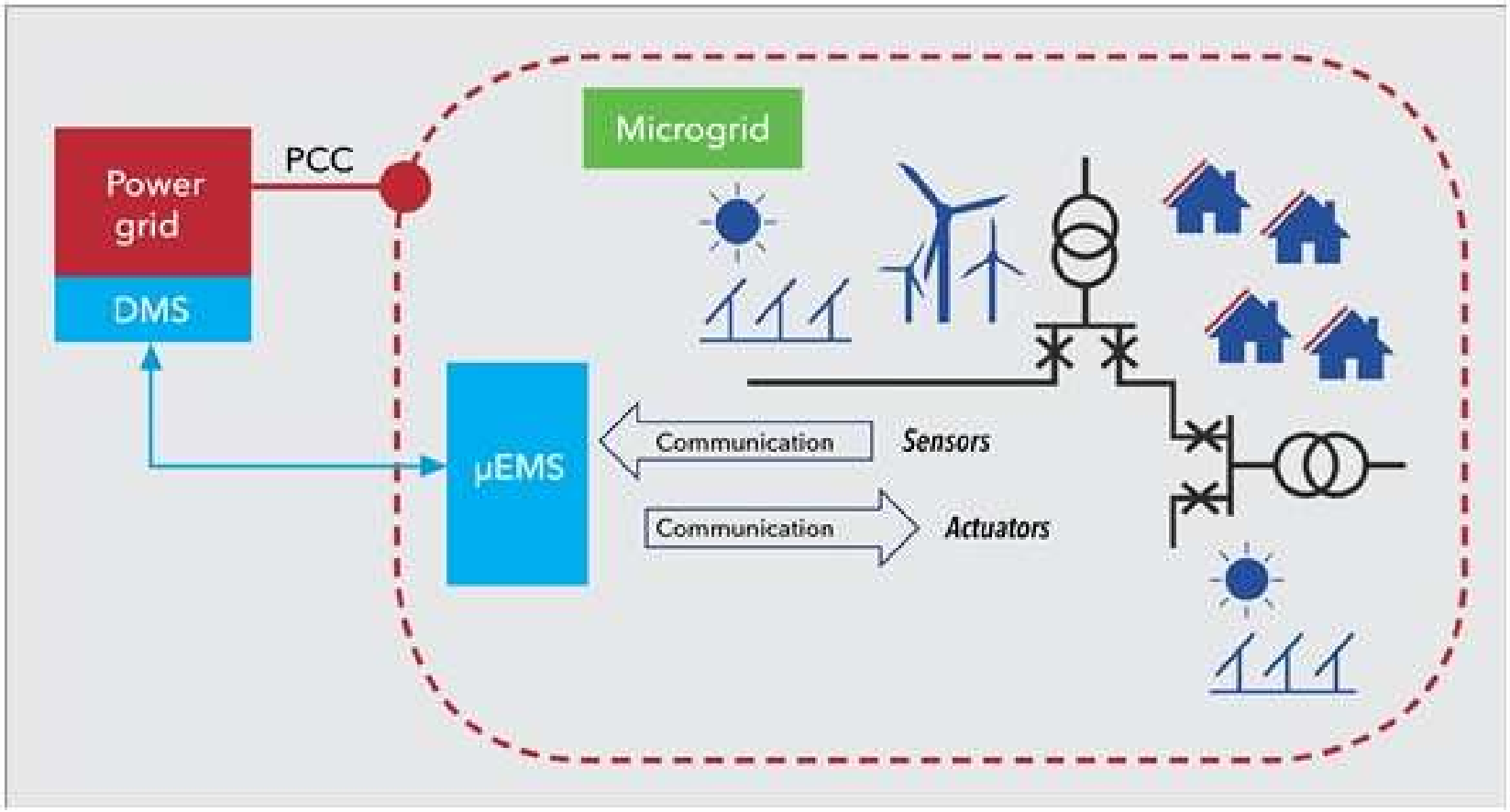
- **VPP:** EMS that aggregates **m**ulti fuel, multi location and multi-owned power stations via advanced ICT infrastructure.
- **VPP**: is a flexible representation of a portfolio of DER that optimizes the economic value of the energy produced, and offers reliability and capacity for ancillary services.
- **VPP Navigant**: A system that relies upon software and a smart grid to remotely and automatically dispatch and optimize DER via an aggregation and optimization platform linking retail to wholesale markets.
- **VPP Ventyx** : ''Adding Customers to the Smart Grid"

EPRI: Integrating Smart DER with DMS, 2012

DERMS: DER Management System, source: EPRI



Micro grid basic concept, source: DNV GL



Existing solutions/case studies for VPP/µG

- **Commercially available**
  - Ventyx/ABB
  - Siemens
  - Bosh
  - GE
  - PSI,
  - Etc.
- **Research projects, pilots**
  - EPRI
  - FENIX
  - Twenties (VPP: Power Hub)
  - Edison
  - E-Badge (VPP as BSP)

- **Case studies VPP**
  - Germany
  - USA
  - Spain
  - Ireland
  - Faroe

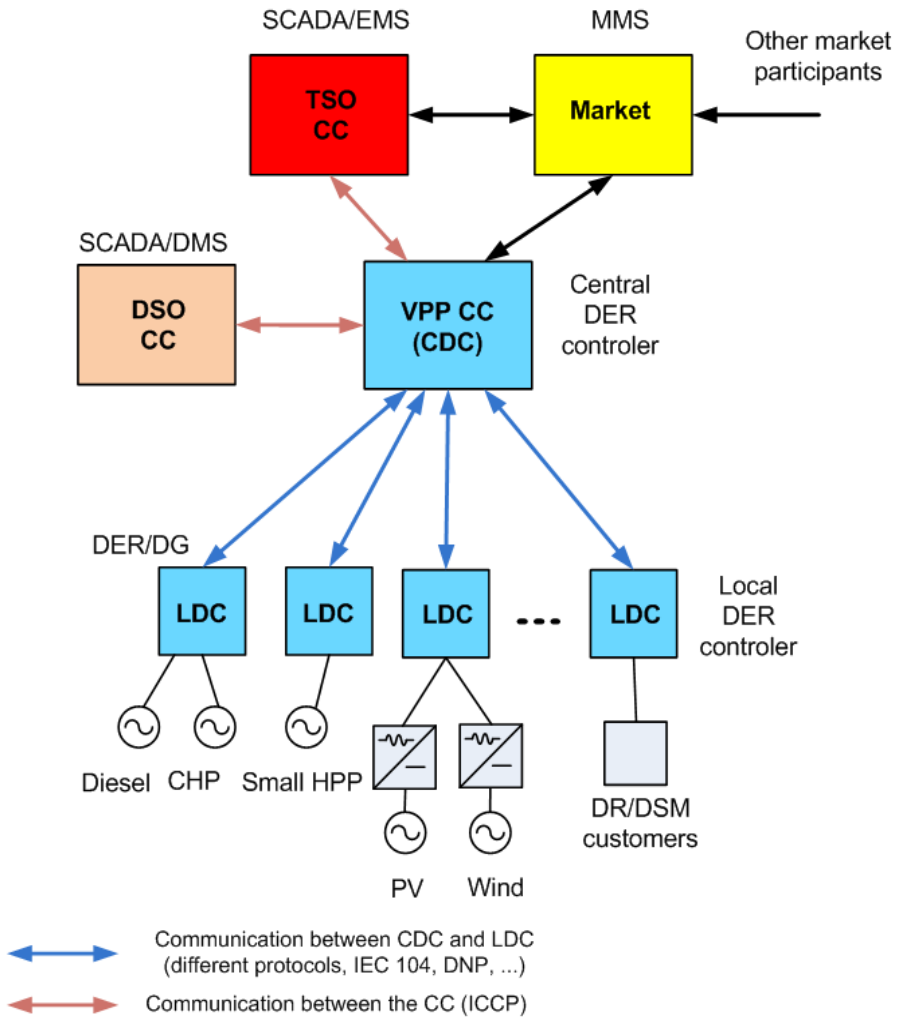
- **Case studies µG**
  - DK: Bornholm,
  - GR: Kythnos,
  - …..

VPP services

- Deliver energy to wholesale market
- Provide reserves (primary, secondary, tertiary)
- Provide Pf regulation
- Provide reactive reserve and voltage regulation
- Provide black start, restoration service
- Load shifting (DSM) and shedding (DR)
- Energy storage (electric, thermal, kinetic), EV

This services can be delivered **under different business models.**

Init. proposed solution architecture



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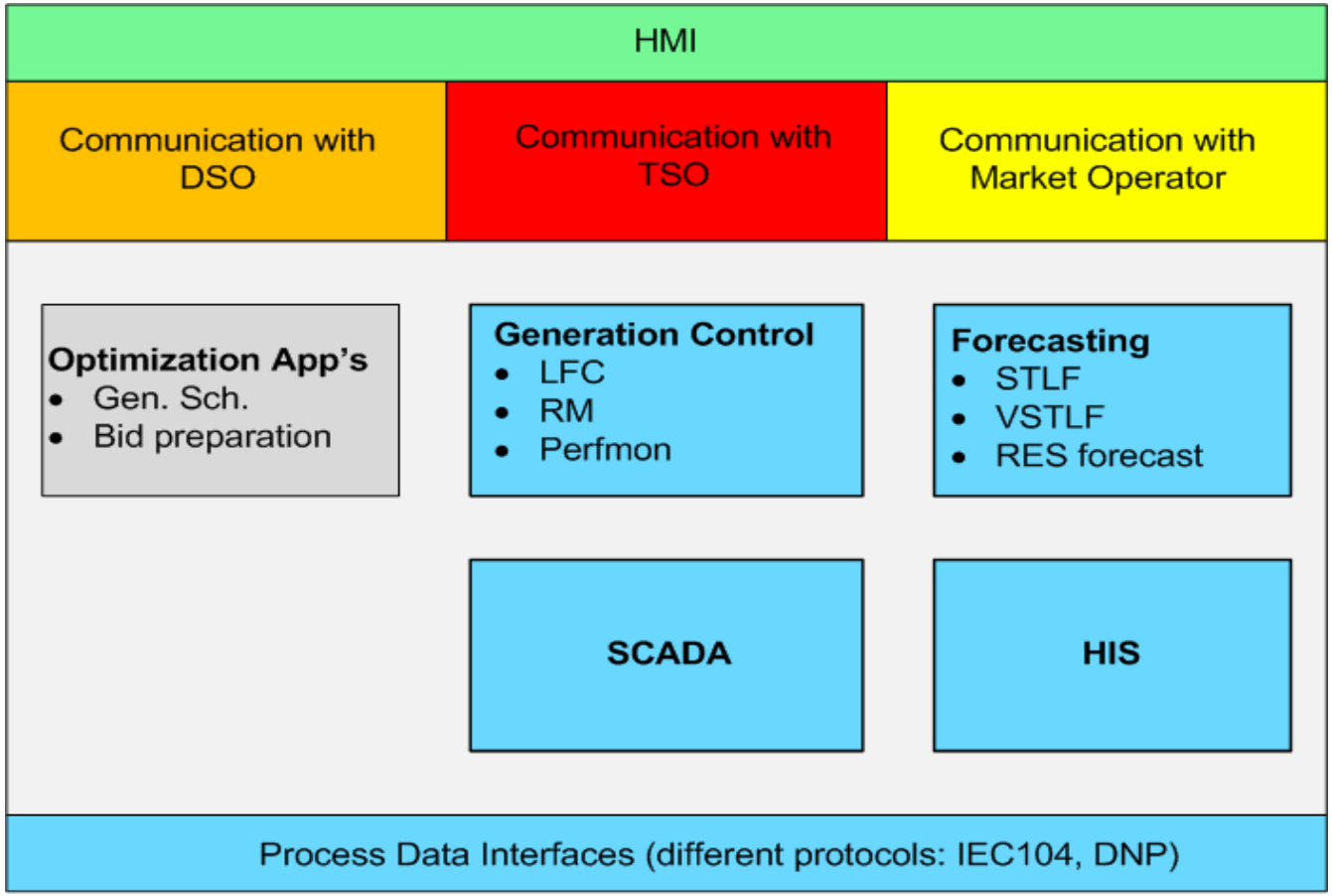
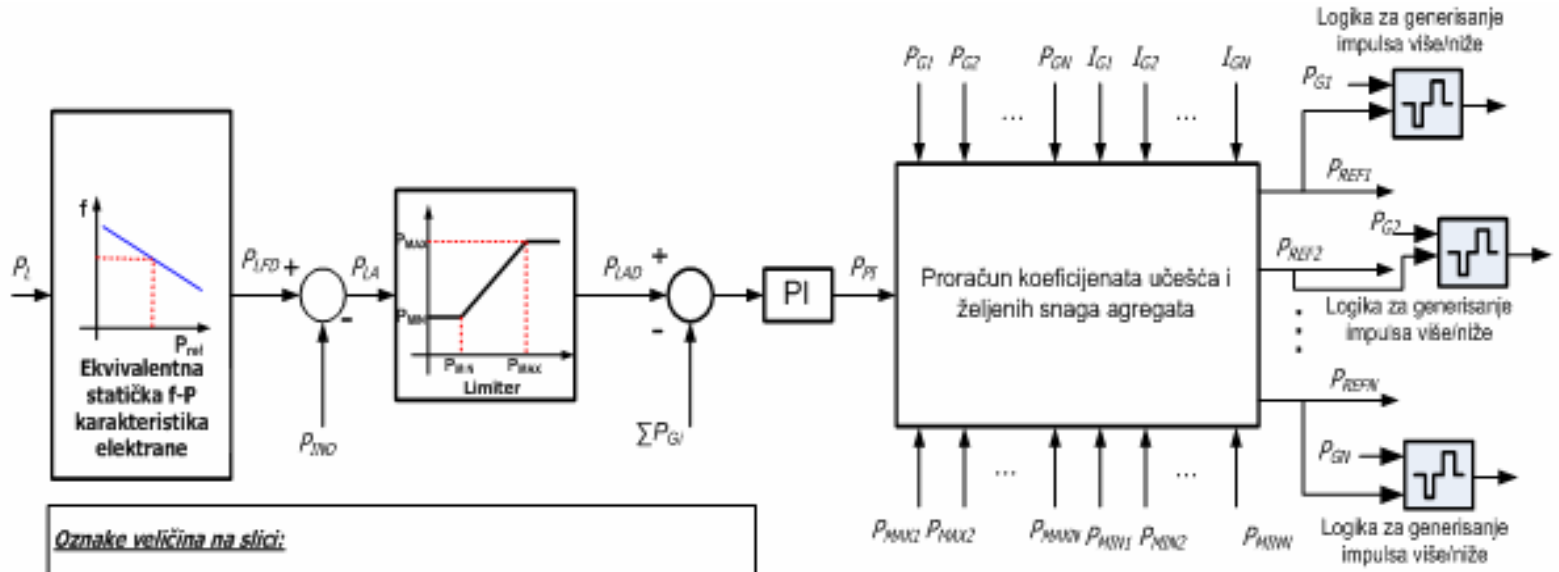
VPP-CC (CDC) Target Architecture



JC4P/Q: Joint active/reactive power controller

- Automatic control of the plants ref. value (P/Q)
- Automatic uniform distribution of power between units
- From the outside multi unit PP is seen as an equivalent single unit (equiv. droop configurable)
- Different operating modes (LFC, Local control, Mixed mode, Monitoring mode)

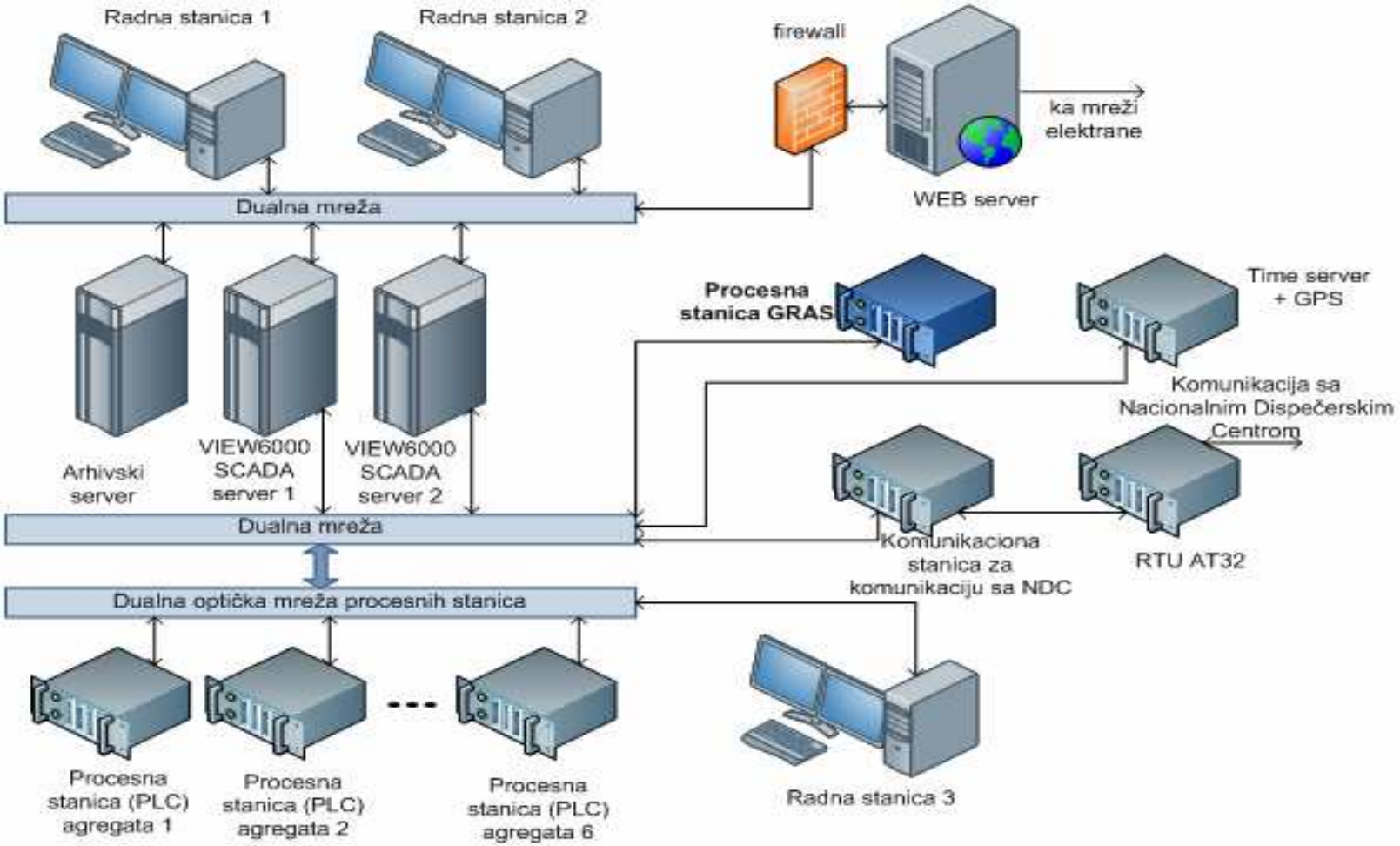
PP level-GRAS (JAPC) structure



Oznake veličina na slici:

- P_L – Referenca aktivne snage elektrane
- P_{LFD} – Referenca aktivne snage elektrane korigovana po ekvivalentnom statizmu
- P_{IND} – Suma aktivnih snaga jedinica koje ne učestvuju u grupnoj regulaciji
- P_{LA} – Neto referenca za jedinice u GRAS P_{LFD}-P_{IND}
- P_{LAD} – Neto referenca za jedinice u GRAS korigovana tako da reference ostanu u dozvoljenim granicama
- P_{PI} – Izlaz PI regulatora
- P_{G1},..., P_{GN} – Aktivne snage agregata
- I_{G1}, ..., I_{GN} – Indikacije da li jedinice učestvuju u GRAS
- P_{MAX1}, ..., P_{MAXN} – Maksimalna dozvoljena snaga za jedinice u GRAS
- P_{MIN1}, ..., P_{MINN} – Minimalna dozvoljena snaga za jedinice u GRAS
- P_{REF1}, ..., P_{REFN} – Željene aktivne snage (reference) agregata u GRAS
- e_{UCES1}, ..., e_{UCEN} – Regulacione greške jedinica
- $\sum P_{Gi}$ – Suma aktivnih snaga jedinica koje učestvuju u GRAS

Example 1: H/W architecture at HPP Djer1



HMI at HPP Djer1

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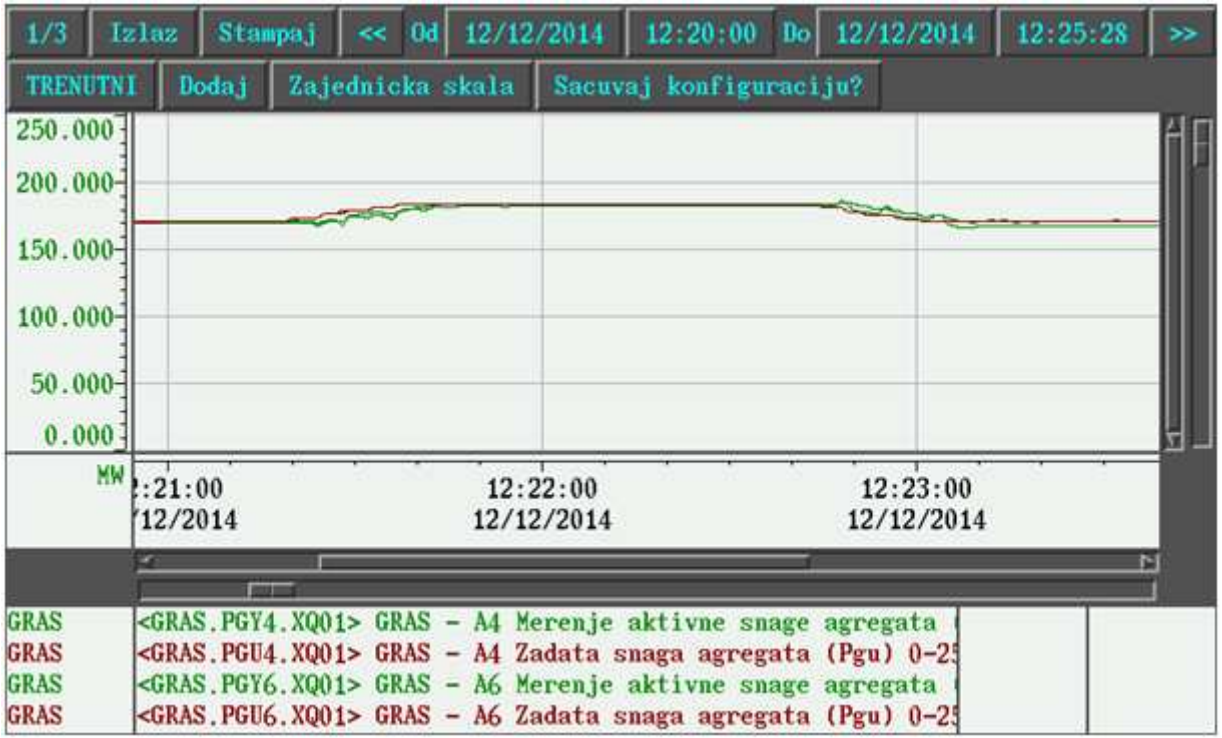
Real response of the controlled units



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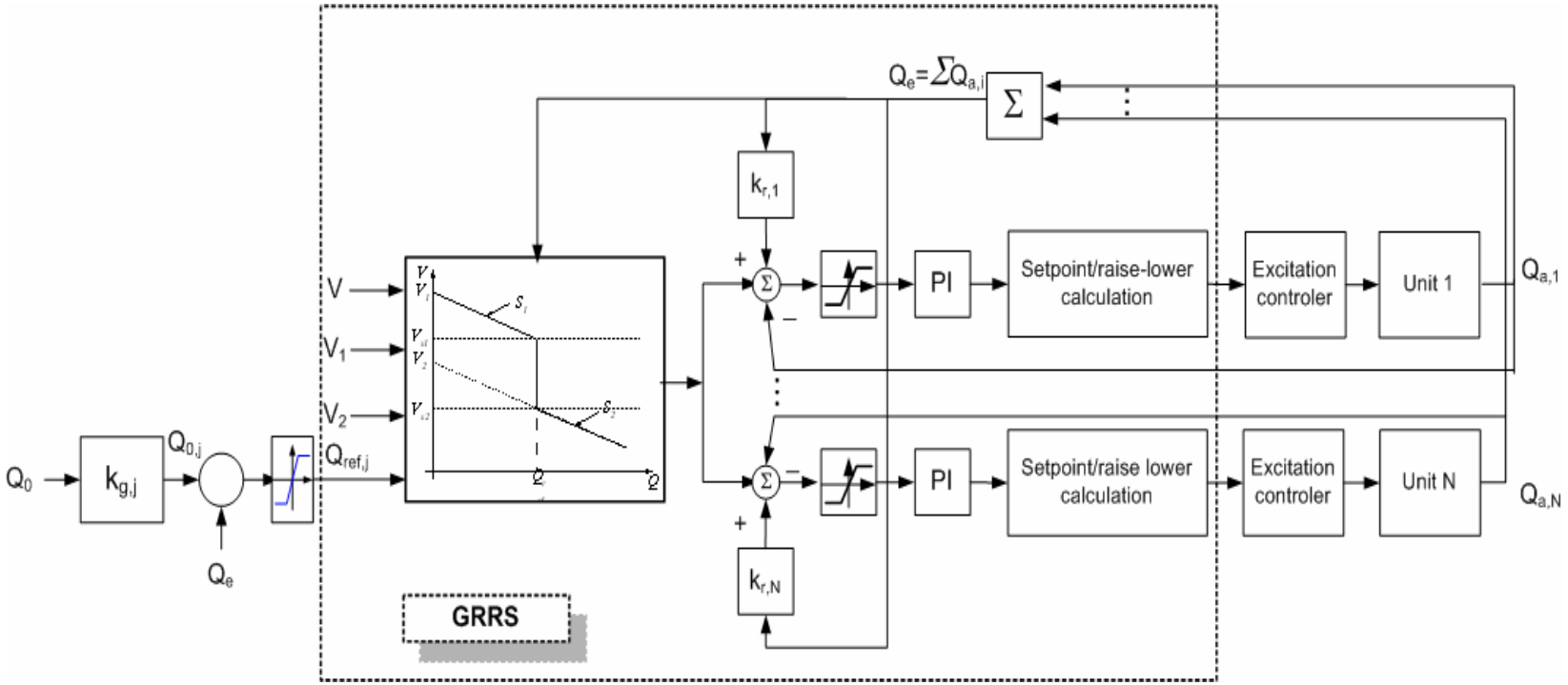
PP level-GRRS (JRPC) structure



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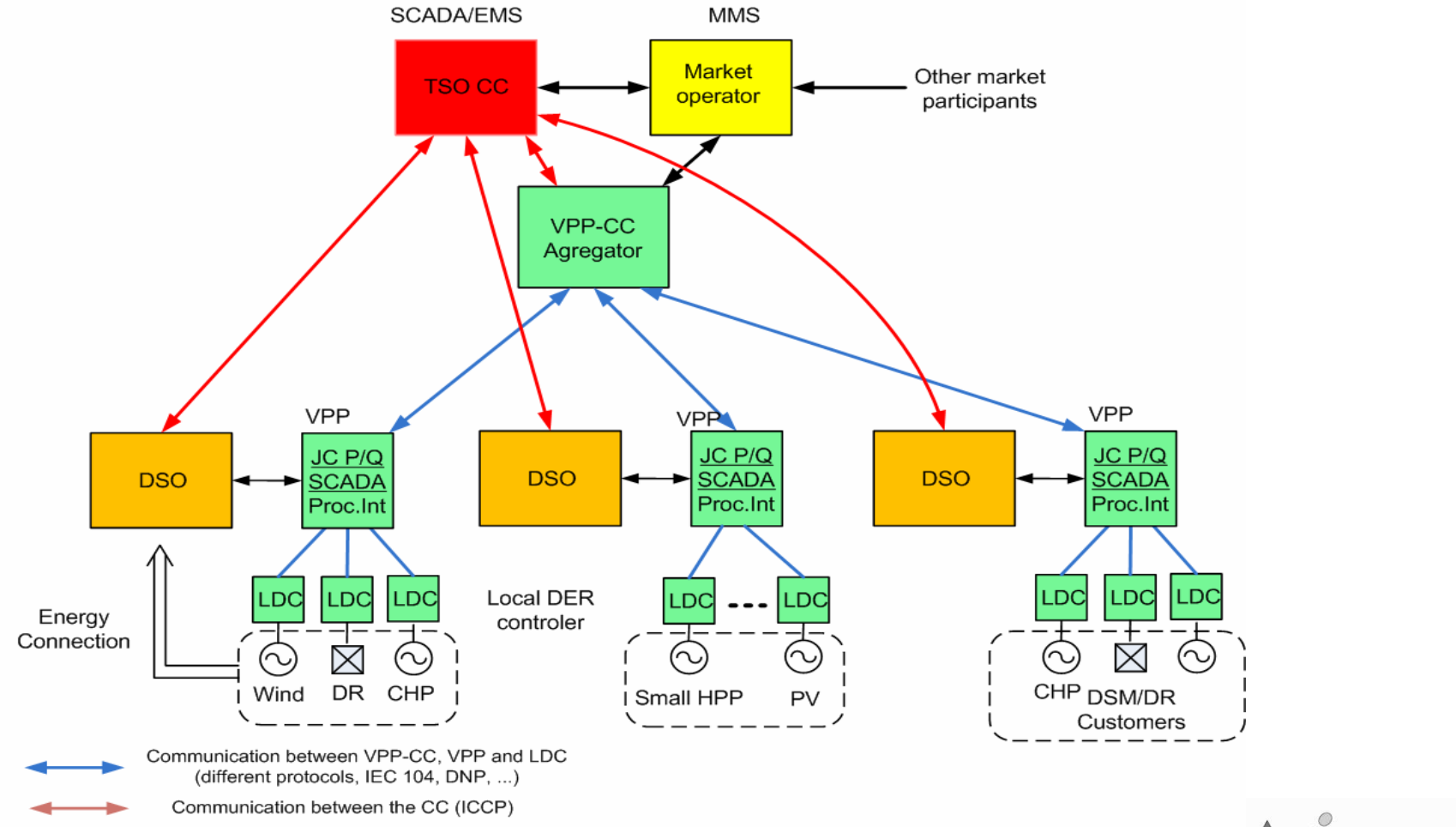
Implication on PS Control Architecture

- Motivation for paradigm change
- Vendors often ”overload” VPP functionality
- Multi level, hierarchical VPP solution
- More flexible approach
- VPP- technically focused (interfacing, comm. ,monitor and control, SCADA, JCAP, JCRP…)
- VPP-market focused (scheduling, bidding, forecasting,…)

Hierarchical VPP solution (VPP-CC, VPP, LDC)



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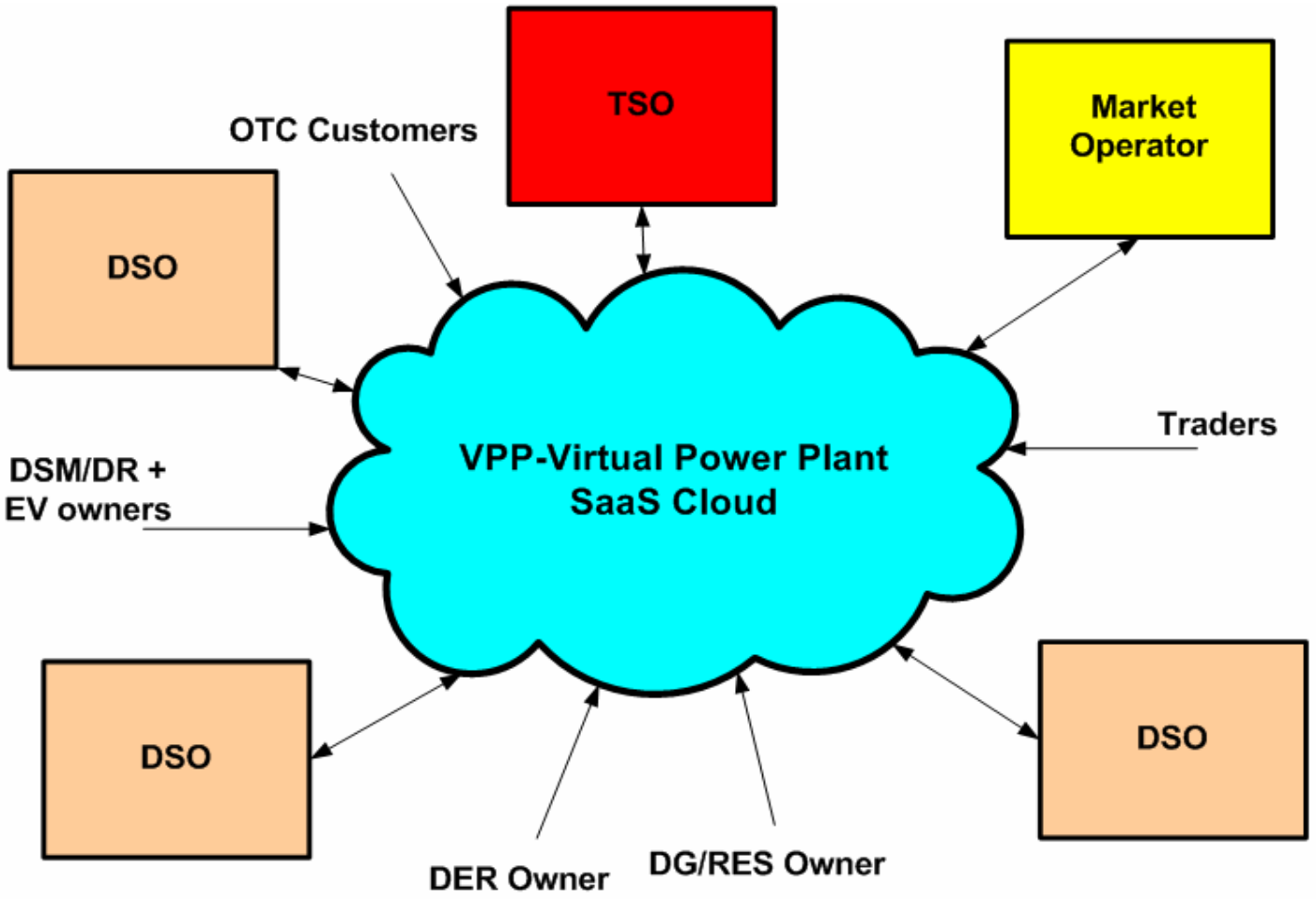
Future ideas, work

- **As number of IPP's, independent DER increase**
- **To grasp small to medium DER owners without enough resources to operate centralized VPP**
- **Idea is to move VPP-CC functionality to the cloud as a SaaS.**

VPP-CC as a SaaS on the Cloud



Conclusion

- Problem: DER aggregation
- **Virtual Power Plants VPP**
- **Existing solutions**
- **Developed local VPP solution**
- **Developed hierarchical solution**
- **Practical tests**
- **Future work**