Abstract – This paper proposes a decentralized approach for the management of distribution systems including dispersed generation. The methodology is zonal approach and multi-agent systems based.

The study presented compares centralized and decentralized methods and draws conclusions about the advantages and drawbacks of each.

Keywords: Dispersed Generation, Storage, Distribution Grid, Multi-Agent Systems, Distributed Optimization, Unit Commitment and Dispatch.

1 INTRODUCTION

The distribution systems are now fundamentally changing. This is due to the fact that a lot of small size dispersed generation units are expected to be installed at the distribution level, that is, in the MV and LV networks [1]. The problem comes from the current design features of distribution networks, which were not supposed to include energy sources. At this level, until now, the energy is bought from the wholesale market, transported through transmission system and delivered to the customers through distribution system. This primary objective is compatible with the arborescent operational network configuration (thus, no loops), the conditions of protection and security assessment design, the wire characteristics, and also the type of customer service. Since the distribution grid is used in strictly open-loop mode and has no energy sources, the currents are unidirectional and consequently the top-down centralized management model is the straightforward choice.

With the actual technology development and the opening of the electricity market, the electrical energy generation will no longer be only profitable for huge size units [1,2]. The latest technological developments are concentrated on small generation units to be installed close to the demand. These units are characterized by high efficiency and preferable use of renewable energy resources and natural gas.

This situation would convey many small size generation units of different nature (including fully controllable and partially controllable) to be installed at the consumption level, that is, in the MV and even LV grid.

Such changes involve the adaptation need at all levels of the distribution grid operation. Indeed, the grid configuration has to be rethought to accommodate the energy sources and to connect them to the local customers. The network may need reinforcement and the grid protection schemes should be adapted to the bidirectional energy flows. The billing system and customer service will entirely change, and the energy sources inserted will need a management mechanism.

Besides, in the context of electricity market liberalisation the grid operation should be separated from the energy generation, as at the HV generation and transmission grid level.

Since the generation sources at the MV/LV level are of relatively small capacity, their generation is normally consumed locally. This specificity and the arborescent topology (feeders with laterals) tend to create zones containing some local generation corresponding to the local energy needs.

In the work presented in this paper this special feature is analyzed, and some propositions are made concerning the possible operation and management strategies.

2 ZONAL OPTIMIZATION APPROACH

Due to all these changes in the distribution grid the question arises, whether the centralized management approach is still the most appropriate. The amount of information to be centrally treated would considerably grow [3], due to the number of generation equipments inserted into the grid and the stochastic operation nature of some of them. Big amounts of data would need to be collected, treated simultaneously and provided quickly for further processes. The presence of the stochastic energy sources and the reliance on the communication system could compromise the grid operation and the security of supply.

For these reasons some problems could be resolved locally. This would relieve the computational burden and would give the system additional security due to the partial decision autonomy. Some issues for which the local solution is possible are treated in this work and are presented below. A local optimization approach is first treated as an alternative to a centralized one. The distribution system is proposed to be operated in semi-autonomous zones. Then several possible applications are proposed, such as the unit commitment and dispatch in such zones. A market design proposal for the distributed energy sources inside the zone is also exposed.
3 CENTRALIZED VS. DE-CENTRALIZED APPROACH

The present study compares the centralized and the de-centralized approaches for the optimal management of a distribution grid in the context of distributed generation presence.

As discussed above (section 2), the traditional centralized management approach may become computationally consuming and also not reliable enough. In this case, the local producers and the consumers have no interaction to each other (that is, no direct negotiations) and the generation is governed in a least-cost way. The centralized optimization does not lead necessarily to the individual optimal profits of both consumers and generators. Consequently, on the production side, it gives no motivation to innovate, and on the consumer side, to optimize the load profile, and thus the energy bills. Both the owners of the distributed generation resources and the consumers are here price takers.

The energy price is then dictated by the large power plants at the wholesale market level, the number of retailers, the transmission system capacity and also other factors such as fuel prices. But, in fact, the distributed energy sources are decoupled from the transmission system. Since this energy is also consumed locally, the distributed energy owners may probably be allowed the direct access to the customers and the local competition, resulting in a local market.

In that context, the optimization method adopted here for the distribution grid is based on a decentralized approach [4]. The grid is divided into interconnected zones containing some local generations (for example, wind parks or and some storage devices) corresponding to the local demand and connected to the transmission grid, so the excess/shortage in zonal energy production can be compensated through transactions between several zones or a zone and the transmission grid. The method proposes to allow the direct interactions between the market participants, which are local generations and consumers inside the zone. In this way a competition is promoted involving the local distributed generation sources and also the wholesale market. Such a situation would also promote innovative technologies, the search for market niche and specific customer services capabilities, and is ultimatively expected to draw the energy price down.

The consumer is proposed to be set entirely eligible (each customer has a possibility to choose among the suppliers) to give it an incentive to optimize its load profile. Small consumers may want to be represented by some kind of aggregators. The interactions between the market participants are assumed to be automated by a distributed optimization algorithm. The zones are supposed to be equipped with communication devices.

4 MULTI-AGENT SYSTEM FOR DISTRIBUTION NETWORKS

The distributed optimization approach adopted here is inspired by the multi-agent systems (MAS) [3, 4, 5, 6, 7]. MAS are characterized by some interaction of a number of agents, working on behalf of their masters. To remind the intelligent agent definition, we recapitulate here their principal characteristics. The agents are defined as rational and are characterized by being: inserted in a context, autonomous, reactive, proactive (taking initiatives in pursue of their goals), flexible, robust to failures and capable of interaction with other agents. All the interactions between agents take place by message exchanges.

The agents are organized in a hierarchical society-like structure, where each agent has its specific role. The individual goals of an agent may interfere with the global goals of the system. In this case the agents are confined to negotiate with each other. The global goal can not be attained without the complete or partial fulfillment of the particular objectives of each agent.

4.1 Multi-agent architecture

The multi-agent approach consists in assigning an agent to each market participant in a particular zone of a distribution grid (fig.1).

According to the structure of the distribution grid containing the distributed generation, there are generators agents GA, load agents LA (individual or aggregators) and zone agent ZA.

The LAs and the GAs are acting on the local level (fig.2), with a primary scope of minimizing costs/maximizing profits.

Figure 1: Zonal multi-agent structure.

Figure 2: Agents’ hierarchy inside and outside the zone.
The zone agent has no own financial goals and represents a service agent acting on behalf of the agents in its zone. Thus, hierarchically, the LAs and the GAs have an intrazonal competence and local knowledge, while the ZAs are designed to optimize the zone as a whole and to perform the interzonal transactions, and therefore possess the global knowledge about their zones.

As only the general concept of multi-agent system was applied, the agents described below were implemented using standard scientific programs such as Matlab.

4.2 Zonal Market

The optimization problem is studied in a frame of a day-ahead market. Local energy sources are in competition with other sources inside and, indirectly, outside the zone. No common price establishment mechanism is used, but the generation is allowed to proceed by bilaterals and to make individual offers to the customers. There are also some external import/export possibilities through the MV/HV transformer linked to the transmission network. This link assures the internal balance in the zonal dispatch but may be used as an additional energy source. The export/import capacity is limited by the thermal limits of this link itself, but also by the agreements between the zone and the transmission system.

4.3 Agents modeling

Generator Agent

**GA Goals.**
- Primary goal: maximization of the generation profit. GA has an incentive to sell the most of its energy at the internal zonal market at the maximal possible price (see section 4.4, *Market Price Estimator*). Otherwise it will enter in conflict with the goals of the zone agent.
- Secondary goal: participation in an overall zone optimization in a way that assures the viability of the zone load supply and also the required power quality. This objective is a part of the global goal of the system.

**GA Actions.**
- Prepares the generation offers for LAs based on the energy resources available, wholesale market price predictions, the past experience, the competition at the zonal market level;
- Interacts with the LAs in order to conclude the trading contracts in the zonal market;
- Collaborates with the ZA concerning the overall zonal optimization, technical constraints respect and in order to insure the zonal market liquidity.

**GA Resources.**
- Negotiation algorithm to treat the load offers in a parallel bilateral way (section 5).
- Internal process optimization algorithm (e.g. storage use).

Load Agent

**LA Goals.**
- To satisfy the energy needs of the consumers,
- To minimize the related energy costs.

**LA Actions.**
- Prepares the load offers based on the GAs offers and the market estimator;
- Interacts with the GAs and ZA to establish the trading contracts.

**LA Resources.**
- Demand model of the user (or user community if represented by aggregator);
- Market price estimation tool (section 4.4);
- Generator offers;
- Load offer calculation algorithm (section 4.4).

Zone Agent

**ZA Goals.**

This agent works on behalf of other agents in its zone. Its goals are:
- To assure the overall zone demand supply;
- To assure the maximal internal zonal generation use, minimizing the energy import;
- To promote the liquidity of the zonal market and incite the zonal energy producers to be competitive inside and outside the zone;
- To maximizes overall benefits of the zone
- To assure compliance with technical constraints inside the zone;
- To contribute to maintain the optimal operation of the distribution network as a whole.

**ZA Actions.**
- Balances internal generation with necessary energy imports;
- Optimizes resources allocation inside the zone (using OPF), minimizing the import into the zone;
- Controls the feasibility of the physical delivery of the zonal trading contracts (performs the load flow studies);
- Concludes extra-zonal contracts with neighboring zones/main MV grid;
- Collaborates with neighboring ZAs and the main MV grid operator concerning overall distribution system security, reliability of supply and inter-zonal market liquidity.

**ZA Resources (concerning the zonal operation).**
- Zonal trading contracts;
- Grid topology of the zone and the corresponding data;
- Availability of energy import/export capacity;
- Energy resources available in the zone after the trading contracts have been set (received from GAs);
- Algorithm of the optimal zonal resources allocation (see section 5.2).

4.4 Agents resources modeling

Demand Elasticity

The zone consumers (or their aggregators) may have an elastic demand. Elasticity is defined as a dependence of the purchased quantities on the energy price (fig. 3).
The eligibility allows consumers to choose among the available competing local generations and indirectly among those outside the zone. But, as some sources in the zone may be of stochastic origin (like wind parks, photovoltaics or other), the amount of energy they can produce during some hours may be not enough to satisfy the total zone’s demand. This means, that the consumers are actually also competing among them to get the cheapest/cleanest energy from the available sources [4]. It is proposed to use a market price estimator as a criterion for the load’s agents in order to discriminate between local sources use and the energy import.

![Figure 3: Demand elasticity.](image)

**Market Price Estimator**

The market price (mp) estimator may be different for each LA and GA. Here, we used a statistical estimator based on the price probability distribution (fig.4).

![Figure 4: Price forecasting model for the mp estimator.](image)

From the wholesale market prices history a price probability distribution is built, which here is supposed to be a normal (Gaussian) distribution. The prediction is built using the mean value of the probability distribution, the tendency and the confidence interval. The confidence interval is calculated using the mean value and the price volatility (here, 5%). For instance, for 95% confidence interval and for a number of samples >=120, we have the mp estimated to be within the following interval [min price – max price] of the normal distribution:

$$\mu(1-1.645*\sigma) \leq mp \leq \mu(1+1.645*\sigma),$$  \hspace{0.5cm} (1)

where $\mu$ is the mean value and $\sigma$ is the price volatility.

We can express this reasoning in a following way. There is a 95% probability that the mp will be lower than or equal to the maximal predicted price (max price), and 5% probability that it will be higher.

Both GAs and LAs can use the market price estimator in order to set their offers. From the price probability distribution, GA/LA can derive the price interval in which it is profitable for him to sell/buy its energy on the zonal market.

For our example, we suppose that GA predicts that the mp is comprised between min price and max price with 95% probability. It means that his prediction of mp is mean price $\mu$. Therefore, GA wishes to sell its energy inside the zone at least for the price resulting from its marginal costs. Otherwise, it is more profitable for GA to sell its energy outside the zone, despite the risk exposure.

On the other hand, we suppose that LA makes the same price prediction. Therefore, LA wishes to purchase the energy inside the zone only if the price is at most max price (see gif. 4, LA price), otherwise it is more profitable to buy outside the zone.

If we suppose for the simplicity, that the marginal costs of the generator equals mean price $\mu$, the common price set for GA and LA lies in the interval [mean price max price]. The agents may negotiate to establish the final transaction price inside this interval. They may, for example, settle the final transaction price at the mean value of the counterparts price offers.

A priori, a market price estimator could provide different results for different agents depending on the number of samples considered as well as on the confidence interval. So, as the GA and LA proceed to negotiation, there must be an intersection between the respective acceptable price intervals, otherwise the offer is rejected. In this case, the LA would address its energy request directly to the ZA, accepting the future wholesale market price.

The price probability distribution shape depends on the price volatility. If the price is stable or even known in advance, the price probability may be discretized to one point only which is mp=mean price. Instead, for the market with high volatility, the standard deviation will be high, and the interval between the mean and the max price will be larger. This would allow the local producers to offer higher zonal prices. In this case, the LA may accept a high zonal price (around or even at max price level) to reduce its exposure to the wholesale market risk.

**Demand Model**

The demand model for the de-centralized approach is based on the reference of demand predictions curves used for the centralized dispatch. In a de-centralized approach the load profile may differ from the inelastic demand forecast values, but the total daily consumed energy is equal for elastic and inelastic demand. The optimization period (24 hours) is discretized in $n$ intervals. At each interval, a minimum and a maximum
consumptions are set. The total consumption of each node and of the whole network remains the same, but it may be partially shifted in time in case of the elastic demand. Inside the band width between the minimum and maximum consumption, the purchased quantities are based on demand elasticity curve (fig. 3).

**Load Offer Calculation**

The load offer calculation is in general case an iterative procedure. As mentioned before, the goal of the LA is the minimization of customer costs under the constraint of supplying the daily energy need.

For a given LA, the problem can be formulated as follows:

\[
\min \left( C = \sum_{i=1}^{n} p_i \cdot E_i \right),
\]

discretized over \( n \) optimization intervals.

Constraints:

\[
p_i = \min \left[ p_i, \ldots, p_j \right],
\]

\[
E_i = \varepsilon(p_i) \quad \text{for} \quad E_{i,\min} \leq E_i \leq E_{i,\max},
\]

\[
\sum_{i=1}^{n} E_i = E_D,
\]

where

- \( C \) are total LA energy costs for a given time period (here, 24 hours),
- \( p_i \) is the minimal energy price offered by GAs for the interval \( i \),
- \( j \) is the total number of generator’s agents,
- \( E_i \) is the energy demand for the optimization period \( i \),
- \( E_D \) is the total daily energy demand,
- \( E_{i,\min} \) and \( E_{i,\max} \) are the demand elasticity function x-axes boundaries (fig. 3),
- \( \varepsilon \) is demand elasticity function.

## 5 INTRAZONAL OPERATION

The zonal interactions take place in two stages. First, at the lower hierarchical level, the trading contracts between the GAs and LAs are set. Then, at the upper hierarchical level, the ZA performs the technical optimization of the trading schedules. These interactions result in a day-ahead unit commitment and dispatch inside the zone.

### 5.1 Stage 1. Trading Contracts

The algorithm for the zonal bilateral trading contract establishment goes as follows.

- Each GA composes a generation offer, containing the available generation quantities and the respective energy prices.
- The generation offer is passed individually to the LAs of the zone. GA may have several offers.
- LAs perform the load offer calculation and submit the load offers to the GAs (if willing to purchase inside the zone), or directly to the ZA (if wanting to import at the market price).
- The GAs treat the LAs’ requests in a “first in – first out” way and conclude the bilaterals with each LA according to their requests if the requested energy is still available.
- If the energy requested was sold before the request is treated, the GA updates the available generation schedule and makes a new offer to the LA agent based on the quantities still available.
- LAs re-calculate their load offers again using the updated information. The procedure is repeated considering all LAs and GAs.
- GAs submit concluded trading contracts to the ZA along with the quantities still available after the trading contracts are concluded.
- The trading session is closed.

### 5.2 Stage 2. Optimization of the zonal resources allocation

While concluding trading contracts, the zonal agents (GAs and LAs) can not verify the physical delivery conditions, as none of them possesses the complete data set about the zone. In fact, the ZA is the only zone agent that do possesses all the information needed to control and, if needed, to optimize the physical energy delivery from GAs to LAs.

To promote the zone market liquidity, ZA tries to match the internal LAs needs not satisfied by the trading contracts inside the zone by the internal GAs supply surplus. This surplus refers to the quantities that GAs did not sell at the zonal market during the trading contract session (section 5.1).

Such operation is possible, if the purchase and sell prices of LAs and GAs respectively are compatible. Here we suppose that both consumers and suppliers, that wish to import or export the energy, accept the wholesale market price.

The calculation is based on an OPF. However, the ZA goal is not to minimize the generation costs, but to optimize the zonal resource allocation. To do this, ZA establishes its own priority order of generation commitment depending on the available quantities, proposed prices or other. For example, the stochastic generation units may be given priority. The possibility to import energy is considered only in case, when it is impossible to serve the zonal load with local generation resources.

In case of technical constraints violation, the OPF may result in the increasing/increasing generation of some GAs. The financial mechanism that settles this congestion problem is not treated in this paper. However, as an example, we can assume the local balancing markets implementation.

The ZA priority order works as an internal market enhancement. Indeed, the fact that some GAs did not sell their energy at the intrazonal market and have a considerable energy surplus to export after the trading session means these GAs are not competitive enough in the zonal market. The prices these GAs offered were higher that \( \text{max price} \) of all the LAs in the zone. If these GAs still wish to sell their energy, their last option is to export it at the wholesale market price.
Obviously, this price will be lower than the price initially offered by these GAs. This is because the wholesale market price, according to the price probability distribution, will lie in the interval \([\text{min price max price}]\) with 95% probability. Therefore, such a GA will receive only the wholesale market price remuneration for its energy production, which motivates it to improve its competitiveness at the intrazonal market.

Upon completing the zonal resources allocation optimization, the ZA obtains the final quantities produced and consumed inside the zone, the energy surplus inside the zone to be exported, as well as the energy to be imported from the extrazonal market. The extrazonal transactions may be concluded between the neighbouring zones ZAs or with the main grid, in the frame of the interzonal operation. This topic is out of scope of this paper.

After the GAs receives the definite schedules from the ZA, they may need to perform some internal process optimization (for example, stochastic generation may need to optimize the use of storage).

5.3 Study case

The described approach was implemented in the example of a portion of a realistic grid [8] (fig. 5), where two distributed energy sources were inserted: a gas turbine of nominal charging/discharging power 3 MW with nominal storage capacity of 50 MWh (representing the controllable generation) and the small wind park composed of 10 turbines of type Vestas V52/850 kW (representing the stochastic generation).

The wind park is equipped with a storage facility with the charge/discharge power of 3 MW. The transversal susceptances of lines are neglected. The loading \(cos \phi\) is taken to be of the order of 0.9.

The 10 min discretization interval is derived from the reasonable wind prediction update rate and is used for the intra-zonal dispatch at the stage of the day-ahead operation planning. The online control algorithm used for the real-time load following during operation is not presented in this paper.

The wind generation prediction time series and the planned availability of the controllable generation are presented on the fig. 6 along with the typical demand curve.

**Figure 5:** Study case network.

![Figure 5: Study case network.](image)

**Figure 6:** Zonal generation and load profile.

![Figure 6: Zonal generation and load profile.](image)

The load curves were adapted from those listed in Swiss Electricity Statistics [9] as a daily spring demand of a small Swiss town of about 7000 inhabitants. This curve was then scaled and applied to all of the nodes of the network. This demand is not elastic and the customers are not eligible. The dispatch results are shown at the fig. 7.

**Figure 7:** Centralized dispatch.

![Figure 7: Centralized dispatch.](image)

For the de-centralized optimization and the load elastic to \(\pm 25\%\) of the inelastic demand, the dispatch results are presented at the fig.8. Here, the main grid-import requests resulting from the stage 1 optimization (section 5.1. Trading Contracts) are when possible substituted by the local generators production (compare the main grid requested imports with the main grid actual imports curves, fig. 8).

Comparing the figures 7 and 8, we can see the distributed dispatch aims at the maximizing of the local generation use and the minimizing of the imports. The centralized dispatch does not account for the stochastic character of the wind generation, because its optimization criterion is the overall least generation costs. This approach promotes the main grid generation due to the economies of scale factor, and makes an inefficient use of the local generation.

In the case of a distributed dispatch, the local generation is used at maximum. However, not all the energy can be produced according to the schedule because of the distribution grid constraints. But the
availability of the storage allows for postponing of the part of that energy for supplying the demand, previously committed to the main grid at the wholesale market price (see fig 8, where the main grid planned generation is above the main grid actual one).

Figure 8: Distributed dispatch

The gas turbine is also, whenever it is possible, used at maximum in the distributed dispatch case (fig. 8). In our case, ZA gives the wind farm a higher priority while performing the OPF. The reason is mostly its renewable energy source, but the priority criteria may also be commercial or strategic. So, as we can see at the figure 8, after overall optimization the import from the main grid is reduced. Indeed, for each optimization period the power imports from outside the zone are minimized. This results in both, overall energy imports, and the mean power import value minimization.

The consumers which are committed to the main grid supply pay the actual market price valid at the moment of supply. The same price is then paid to the local suppliers which is equivalent to selling the generation surplus outside the zone.

The wholesale market price estimation and the real price modelled with 5% volatility (white noise) are presented in the fig. 9.

Figure 9: Wholesale market prices modelling.

The market participants’ profits are listed in the table 1 below. Here, the planned transactions refer to the final dispatched generation quantities inside the zone, and the potential transactions concern the generation surplus that has not been dispatched inside the zone and may be sold outside the zone boundaries.

As we can see, the total benefits of the zone producers are higher in the distributed dispatch case. This happens because the main grid generation import is reduced to the necessary minimum. As a consequence, the load part that was previously supplied by the main grid is taken over by the local suppliers. Moreover, there is a possibility for the local suppliers to export the energy surplus outside the zone.

<table>
<thead>
<tr>
<th>Benefits (+) / Costs (-)</th>
<th>Centr.</th>
<th>Distr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind gen. planned transactions</td>
<td>2.761</td>
<td>3.185</td>
</tr>
<tr>
<td>Wind gen. potential transactions</td>
<td>1.996</td>
<td>2.110</td>
</tr>
<tr>
<td>Wind gen. storage expenses</td>
<td>-1.286</td>
<td>-1.429</td>
</tr>
<tr>
<td>Total zonal benefits wind gen.</td>
<td>1.475</td>
<td>1.756</td>
</tr>
<tr>
<td>Conv. gen. planned transactions</td>
<td>4.356</td>
<td>4.431</td>
</tr>
<tr>
<td>Conv. gen. potential transactions</td>
<td>0.371</td>
<td>0.044</td>
</tr>
<tr>
<td>Total zonal benefits conv. gen.</td>
<td>4.356</td>
<td>4.475</td>
</tr>
<tr>
<td>Main grid profits</td>
<td>2.008</td>
<td>0.482</td>
</tr>
<tr>
<td>Total zone users costs</td>
<td>- 9.100</td>
<td>-8.182</td>
</tr>
</tbody>
</table>

Table 1: Benefits and costs: centralized vs. distributed dispatch, k$.

The users’ costs are lower in case of the distributed dispatch, because of the users demand elasticity and the corresponding price signals from the suppliers inside the zone. From the fig. 10 we can see, that the elastic demand in a market environment is capable to match the available generation, which help to reduce the peak-hours load and to partially shift the consumption to the low tariffs/low load periods.

Figure 10: Elastic vs. inelastic demand.

6 CONCLUSIONS

In this paper the decentralized optimization approach is explored to integrate the dispersed generation in the distributed grid. The developed method proposes to operate the distribution grid by zones and to set up a zonal market, in which the prices may differ from the wholesale market prices. The method is based on the
intelligent agents approach. The optimization is split in two stages: the trading contracts session between each generator and each load agent, and the overall zone technical optimization session performed by the zone agent on the basis of the trading contracts. The first stage promotes the competition inside the zone leading to the higher local market liquidity, the overall zonal prices reduction and the consumers’ welfare maximization. The second stage is oriented at the optimal technical operation and the necessary interactions between the zones of the distribution grid to find the local solutions without complete centralized revision of the whole distribution grid settings.

This approach was studied on the example of a portion of the distribution grid in which two dispersed energy sources were inserted: a controllable and a stochastic one (including storage). The results obtained show that the distributed unit commitment and dispatch is efficient and results in a better use of the local generation resources, higher competitiveness and the distribution grid autonomy. It also allows for reducing the customer costs for the same energy amount consumed.

Only the intrazonal operation is presented in this paper. However, the interzonal transactions are an important part of the zone agent activity. The neighboring zones may jointly solve some local problems of the distribution grid operation without a need for the centralized re-dispatch of the whole distribution grid. The distributed optimization using intelligent agents approach may help to address some other distribution grid operation topics, such as voltage control.

REFERENCES


