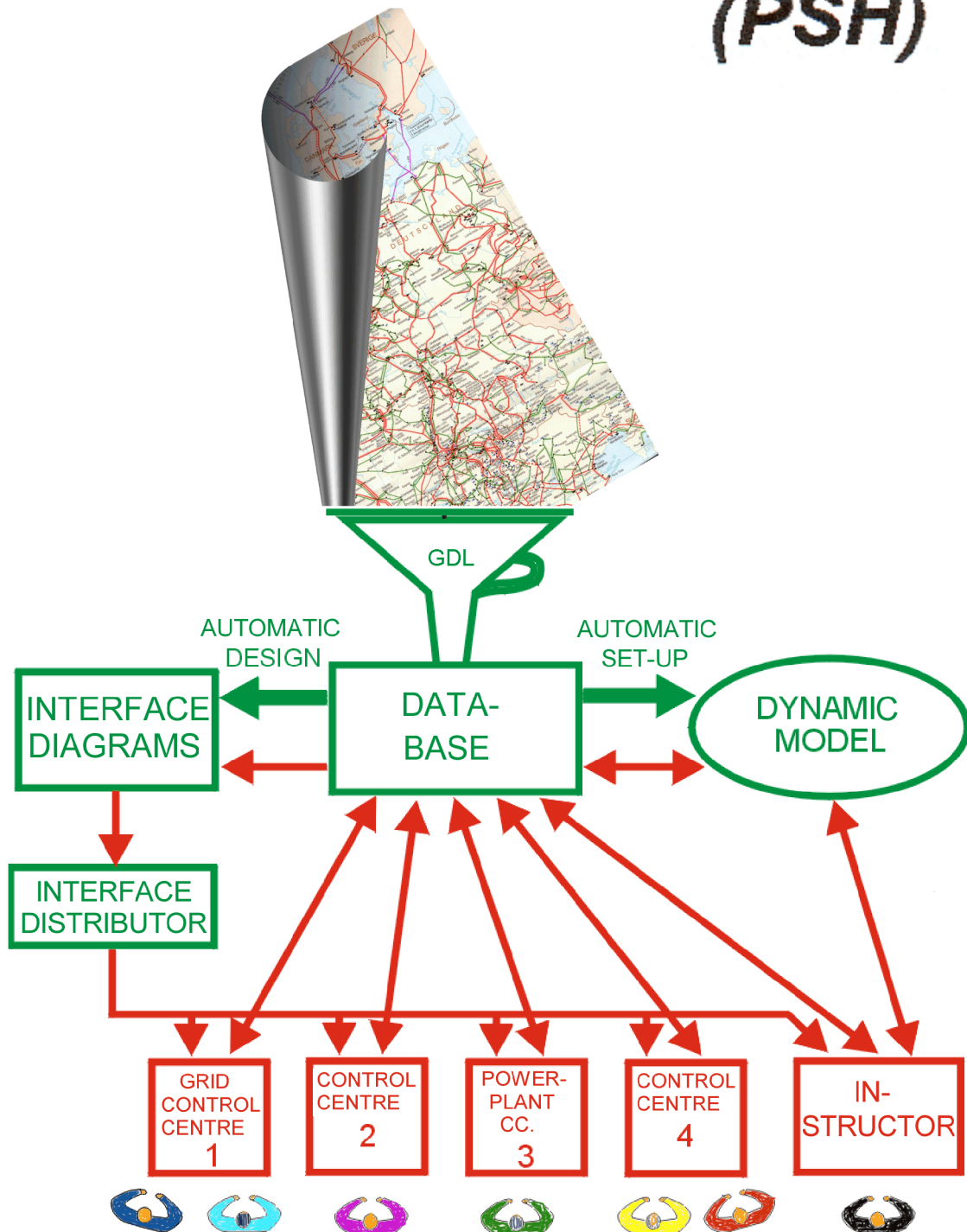


# DUtrain Power System Handler (PSH)



A short introduction to the DUtrain

## PowerSystemHandler

The **DUtrain Power System Handler** was developed to be a training-simulator, and the training of power system operators remains one of its main applications. Additionally to this task, it has found further applications in power system studies and –planning. Therefore it got its present name.

### 1. Training-Simulators in general

- A training-simulator differs from a general simulation-system in the following features:
- It handles **several processes** – i.e. all which are relevant for the training – **in parallel** or quasi-parallel.
- It computes these processes in **real time**.
- It outputs the results of the computations to surfaces, which are comparable to **interfaces for real operation**, and allows to control (to switch and set values to) the simulated processes interactively from these same surfaces.

The production of the “real operation” surfaces, in most cases is much more expensive than the establishment of the simulation programs behind them. Thus, a training-simulator is better characterized as a control centre, the real process of which has been replaced by simulation programs.

Some training-simulators indeed possess a double of the real control environment – e.g. a cockpit or a control room. But, the more realistic the surface, the more costly the installation will be and the more restricted the number of users will become, because the outfit of one control room is not necessarily comparable to another one.

Commercial simulation systems try to use a universal programming style, giving the facility to parameterise them for any given phenomena and time-scales. In their applications usually one run over a limited time-period is studied. With training-simulators the situation is simplified on one hand, because the simulated time scale is limited by the observation facilities in the control centres and the human reaction speed, and is a priori known. On the other hand it becomes more difficult, because all phenomena which can be observed from the control centre have to be computed not only in parallel, but also in continuous run.

### 2. Operators’ Training-Simulators for Electrical Power Systems

Training-simulators for electrical power systems - as additional drawback - experience a data-problem: Even as the simulated physical processes are identical, the structure of each given power system is geographically and historically conditioned; therefore, its topology, its operational possibilities and limits as well as its naming philosophy and operational terminology are individual. All this has to be mapped in training, and it also results in a continual data service to adapt the model to expansions and amendments of the simulated network.

Further, already the data collection and coding for one single power system is rather expensive, because it is not sufficient to codify one single switching state (the actual topology) of the network. In operational view the actual topology is a variable which is due to continuous amendment by switch-commands. Therefore all existing equipment and its mutual connections inside and outside

of the substations (the potential topology) must be coded, and a book-keeping over all their switch-states must be kept up-to-date; thus to enable the derivation of the momentary actual topology to be simulated. Additionally, the data of alarms and measured values put out from the primary-, secondary-, and auxiliary plant of the substations, as well as the established operational network- and substation-diagrams and formats have to be managed.

Therefore, an often applied solution is, to use the data-sets and surfaces of an existing control centre a second time for an “**attached**” training-simulator. The separate data-coding for the simulator is then reduced to the data of power system components which are normally not present in the control centre computer (power plants, protection-settings etc.). Of course, the training-application of the simulator then remains restricted to the personnel of this very control centre.

### 3. The DUtrain PowerSystemHandler (PSH)

The **DUtrain PSH** for the operation of electrical power systems is a **stand-alone** version. This means, it is not attached to any control-room hard- or software and is capable to model any given network – also yours – with all operational data. Of course, in this case the data-problem hits with full power. To overcome this problem, the **DUtrain PSH** provides the following facilities:

- An efficient data-collecting and -handling system (named GDL, for Grid Data Language).
- An automated design of the operational diagrams and formats from the process data-base.
- Finally, the GDL data-system allows to separately describe several parallel or hierarchically neighbouring networks, and to connect their descriptions in the data-base. Vice versa: to distribute the simulation-results back to the surfaces of several “control-centres” simulated in a PC-cluster

By these means it becomes possible to train the cooperation of operators in different control-centres ( load-dispatchers, transmission / sub-transmission / distribution control rooms, power-plant management centres), as it is especially necessary in grid-restoration after major disturbances.



**Fig 1: Training of the operators of 6 control-centres in inter-utility cooperation at DUtrain (open communication)**

The DUtrain PSH has been used as training simulator since 1992; first at the Gerhard Mercator University at Duisburg, and is applied since 1996 by the **DUtrain** company (cf.

<http://www.dutrain.de>) for power-system studies and training courses. The power-system operators participating in the courses have the chance to experience the performance of their own power system in very uncommon operational and disturbed states, and are schooled in overcoming the disturbances by cooperation of – according to the problem – several control centres.

Per simulated control room, up to 4 monitors are provided for the output of switching-diagrams, alarm-logs and measurand-records.

**Fig. 1** shows training with **open communication** of 6 “control-rooms” with 4 screens each. At other training-stages wooden boards are inserted, allowing only telephonic information-exchange between the “control-rooms” (**Restricted communication**, see **Fig 2**).



**Fig. 2: Training with restricted communication between “control-centres”**

#### 4. Updating the PSH

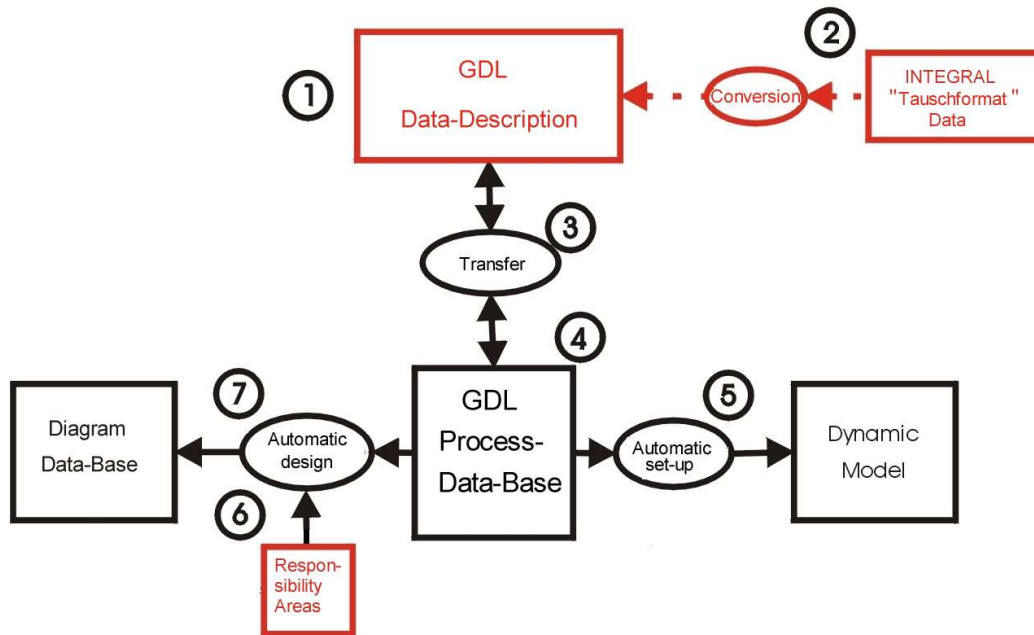
GDL is a language-oriented data-system. Its source description of a network in principle consists of four files:

- The **Dictionary** – according to the operational terminology used by the operators of the individual network - defines name and type of the single operational objects and, by a pointer, connects attribute-sequences to them.
- The **Attribute-source** defines attribute-sequences pertaining to object-types
- The **Network-source**, which - using operational terminology - describes all operational objects, alarms and measurands as a continuous text. By means of an extension of the operational syntax, at the same time the hierarchical structure of the network, the connections of the objects inside and outside of the substations, the connections to neighbouring networks and power-

plants – i.e. the full potential topology - are described. Syntactically, the network-source is articulated into many descriptions of the single substations plus one or a few line-lists

- The **Power-Plant source**, into which the power-units for type and parameters are entered.

Only the **Dictionary** is format-bound, the other files are syntactically structured and can be written down with an ASCII text-editor. For convenience, the GDL system contains a special editor, which provides the Dictionary-format as well as predefined texts for parameterising the power-units. It further employs a topological and semantic consistency-check over all files.



**Fig. 3: Updating the DUtrain PSH**

(1) Basically, each entry into **GDL Data-Description** consists of a hierarchically structured descriptor, which reads:

**Location, Object, Attribute sequence.**

The location in its turn consists from a three-level technological address (e.g. Substation – Voltage level – Bay ). By chained notation of Location and Objects in an ASCII text, the structure of the plant as well as the existence of the Objects within this structure is mapped. Attributes can be entered already into the source description and from there are transferred when setting up the process data- base. But this way is only useful for Attributes which are not variable in operation (e.g. line parameters or design parameters of power plants). Otherwise, operationally variable Attributes (e.g. OPEN/CLOSE of switches or the power set-values of power plants), during training are under continual change by operator- and instructor actions. As one and the same power system description shall be used for different training tasks with differing initial values, it is of advantage to collect this relevant set of initial Attributes in form of **Scenarios** (see section 6), and feed them to the process data-base prior to the training run.

For the GDL-description of a typical network under the responsibility of one control-centre, containing 50 substations with all auxiliary equipment, alarms and measurands, the four abovementioned files comprise about 500kByte and are conveniently transportable on a floppy-disk.

(2) Using a conversion-program, data of the **INTEGRAL Data-system** (A data system inaugurated by FGH and applied by German utilities) can be transformed into GDL-text. Unfortunately INTEGRAL does not provide tools for coding the potential topology of switchyards and substations, therefore these texts have to be further reworked according to the substation-maps.

(3) The **source-texts** of the four abovementioned files are then – somewhat condensed and automatically furnished with access-pointers – entered into the **GDL process data-base**. Important for the process application is, that the alphanumeric operational names as well as the topological syntax remain fully existent for use by the application programs. The condensation-process is fully reversible. Thus, source texts – with or without attributes entered in operation – can be easily regained for amendment.

(4) The **GDL process data-base** is pivotal to the system. From here, the automatic set-up of the Dynamic Model as well as the automatic design of the process surfaces starts. In the later operation of the PSH, all surfaces and all models draw their variable information from here, and computation results as well as the inputs of the operators are entered here as attributes via the event-processing. Only some information can be immediately exchanged between instructor and Dynamic Model.

(5) The **Dynamic Model** comprises the following single models:

- The **Topology-Evaluation**, using the potential topology of the GDL process data-base and the switching Attributes entered there, constructs in each step of the main cycle the actual node/branch topology for the power-flow, and manages the retransmission of the power-flow results as attributes to the places, where measurands are mentioned in the Network-Description. If **more than one topological island** is found by the Topology Evaluation, then the islands are computed one after the other and the following programs are instructed and parameterised accordingly.
- The **Power-Flow** (full Newton-Raphson)
- The **Load-Model** for point-loads and load-trajectories
- Single Models **for power units** of different types (long term performance)
- The **Frequency Model** (medium term performance)
- **Limit check**
- **Synchronizing equipment** in substations and power plant
- **Models for Network-Protection** (models for load-shedding relays and overload protection, differential and distance-protection)
- **Models for Power-Plant Protection** (under/overfrequency-, overload-, excitation- and motoring-protection)

The single **models of the power-units** are set up and parametrised immediately from the source-lists. The PSH provides models for

- thermal units, coal, oil, or gas fired
- gas turbines
- hydro generation
- combined cycle thermal units
- nuclear units
- wind power generation
- external in-feeds from neighbouring interconnected grids

The **load-Model** is collected from the point-loads found in the Network Description.

A **Frequency-Model** is set up for each network island. It runs in 100ms-steps and is re-parameterised in each step of the main-cycle according to the lumped inertias, loads and power found in the island.

Models for **synchronizing equipment** are set up ad hoc during the operation of the simulator, whenever a close-command is set to a breaker fitted accordingly.

The **fault-protection, overload- and motoring-protection models** are connected to the GDL process data-base, the **load-shedding relay** and **under/overfrequency-protection models** are immediately connected to the Frequency Model of the proper island.

For advanced training purposes with operators from interconnected systems the simulation environment includes a model for an **AGC**, Automatic Generation Control.

Furthermore a **short circuit calculation** is available.

(6) The GDL process data-base may contain the representation of an interconnected power system, consisting from partial networks and power-plant groups, which in reality are controlled from different control-centres. If these partial networks and their control facilities shall be mapped also in training, then the simulator must be furnished with information about the circumference of the partial groups and their relation to control centres. Therefore, in the file **Responsibility Areas** these partials are defined and given a name. The definitions may overlap (e.g. to allow the facultative control of a switchyard from two control centres). Later, before training, the PCs mapping a control-centre are attached by calling the name of the relevant Responsibility Area from the PC(s). In that way, the access of the PC becomes restricted to the proper Responsibility Area. For the instructor, the access to the total power system as well as to all single networks and power-plant groups is maintained.

(7) Designing the operational surfaces of the PSH, the following principles were pursued:

- Maximal flexibility in mapping different networks and network-types. That means doing without special hardwired set-ups and best use of monitors.
- In the extreme condition of a simulated cooperation of many control rooms, it should be possible to output all operational data of one control on one screen. That means organisation of data into several parallel or sequentially selectable windows.
- A lucid and easily surveyed mapping of the network, especially for switching operation. That means distribution of the data into hierarchically articulated diagrams with easy and fast transition between them.
- The possibility of an automatic design of the surfaces, either ad hoc in operation or in a preparatory run of the PSH

In these endeavours, the syntactical structure of the GDL-text, which parallels the hierarchy of substations and switchyards in the network, could be profitably used.

The automatic design in a preparatory run comprises the survey- and switchyard-diagrams for switching and control. The other surfaces are prepared – regarding the Responsibility Areas - just in time when called for by the Operators or the Instructor.

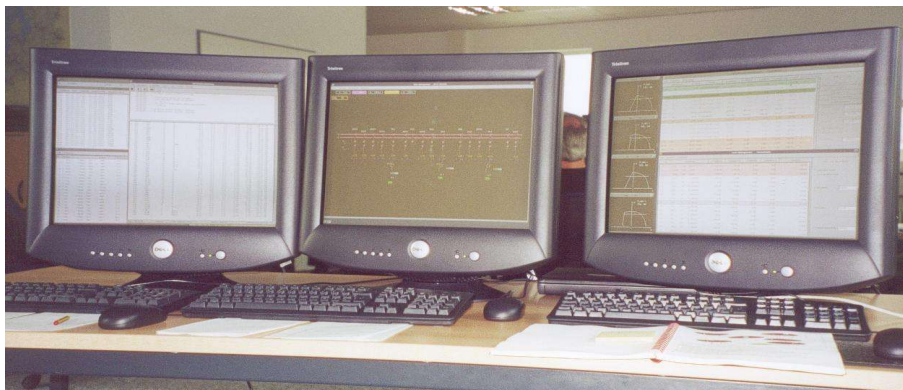
## 5. Operational Surfaces

For **switching operations** (see **Fig. 4**), each Responsibility Area is mapped in a **virtual network diagram (survey diagram)** with approximately geographically positioned substations as box-symbols. If the virtual network-diagram is too big to be placed on the screen in total, then pannable clippings are presented which, using a small navigation-window, can be shifted over the full virtual area. The navigation-window repeats in condensed form the whole virtual area and shows event-bearing substations blinking red. Thus, also alerts to substations presently not on the screen are output and can be navigated to in a step.

Voltage levels are coded by colour; boxes of substations with more than one voltage level handled in training appear white (black in printouts). The survey-diagram dynamically shows open line ends and 4 alarm-icons per substation/switchyard.

In the preparatory run all pictorial elements of the virtual diagram – i.e. substation-boxes, lines and cables – are automatically generated and connected to the process data-base. The positioning of the substations in the virtual area is done interactively by mouse-click, the finished survey diagram is then stored in the diagram data-base.

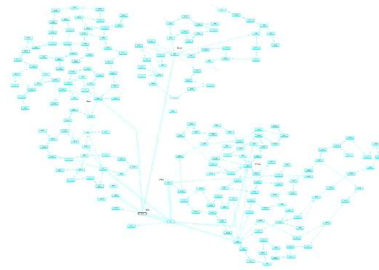
- For further navigation in and between the operational diagrams the following facilities are provided:
- The **substation-boxes** are “opened”; i.e., when clicking at a box in the survey diagram, the box is replaced by a **nodal diagram** of the relevant substation. It remains connected to the survey diagram and shows the actual internal connection state of the substation. The space for imbedding this nodal diagram is gained by an elliptical expansion of the survey diagram. If a substation contains more than one switchyard (“white box”), then, in a first step, an **intermediate diagram** with boxes for all present switchyards appears, from which the desired switchyard can be selected. In that way it is also possible to “open” several boxes in a row, for to follow-up actual through-connections over several substations.
- The survey diagram as well as the intermediate diagram provide the facility to click onward to the detailed **switchyard diagram**. This diagram shows the map of the switchyard with all busbars, bus selectors, breakers, isolators and measurands; it also provides for interactive control of this equipment. If – as with very large switchyards – the busbars are longer than the screen, the diagram can be scrolled.
- By clicking to the line-ends and transformers shown in a switchyard diagram also the diagrams of the switchyards **at the other side** of the relevant piece of equipment can be called for. This feature simplifies the switching of transformers and lines at both sides.
- Actual **nodal diagrams** of switchyards are designed and imbedded “**just in time**” when clicked for; the automatic design of the diagrams of all switchyards is started after updating the GDL-database. The latter diagrams are kept in the diagram data-base.



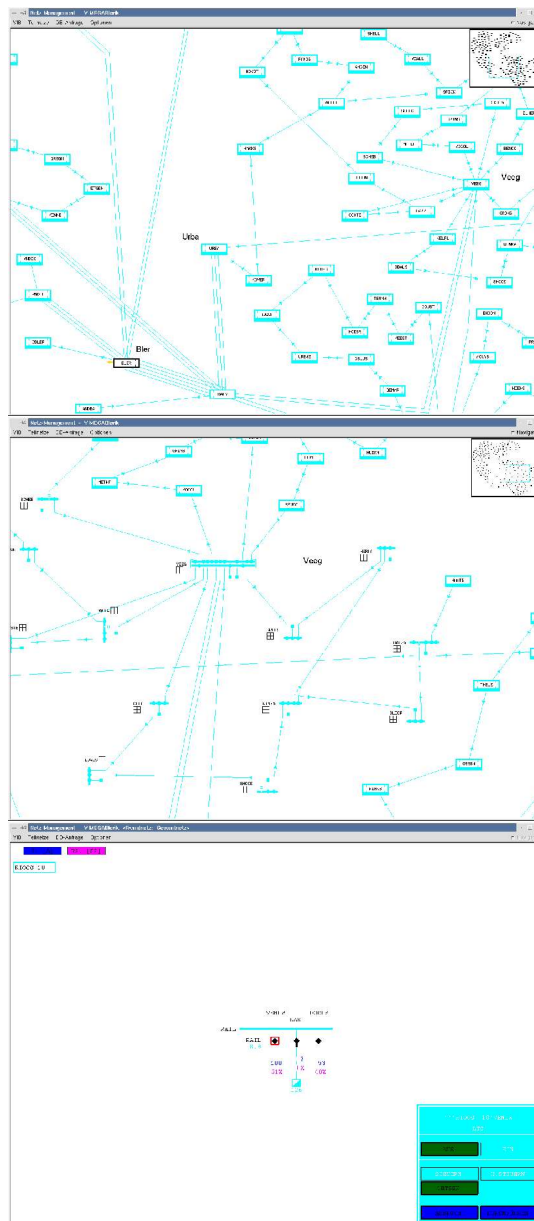
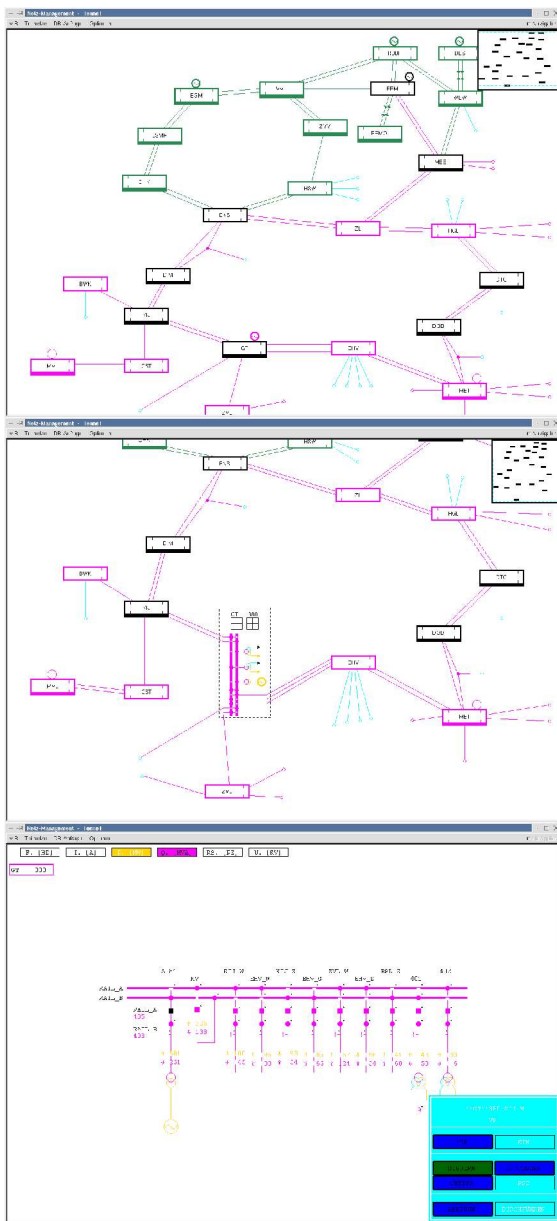
## High Voltage Grid

## Medium Voltage Grid

Virtual diagram of a network that is larger than a screen



Navigable section of it, as it appears on the screen



Section with substation boxes "opened"

Diagram of a substation with breaker clicked and a switching window distribution kiosk

Fig. 4: Windows for switching and survey

## Power plant control

The top left shows three graphs labeled MDC 4, A 91, and MDC 2, each displaying a power (P) vs. heat rate (Q) curve with a specific  $P_{nen}$  value (160 MW, 645 MW, and 83 MW respectively). The main window is 'Einschaltungs-Management - Gesamtnetz', showing a table of power plant units with their status and power outputs.

Blockname	Typ	Zustand	Pnen[MW]	Psoll[MW]	Pbrutto[MW]	Pnetto[MW]	Gbrutto[MVar]	Usoll[%]	Grenze	Warnung
KW_E 1	DKW	●●●●	72.00	5.50	0.00	0.00	0.00	100.00		
KW_E 2	DKW	●●●●	140.00	127.00	126.51	115.11	-3.81	100.00		
KW_SG 1	DKW	●●●●	385.00	12.00	0.00	0.00	0.00	100.00		
KW_SG 2	DKW	●●●●	140.00	110.00	109.31	98.68	-6.71	100.00		
KW_K 1	DKW	●●●●	747.00	30.00	0.00	0.00	0.00	100.00		
GUD3 DKW	DKW	●●●●	25.00	25.00	24.88	22.88	-4.28	100.00		
KW_RS 1	GT	●●●●	38.00	0.00	0.00	0.00	0.00	100.00		
GUD3 GT_A	GT	●●●●	25.00	25.00	24.88	24.76	-4.29	100.00		
GUD3 GT_B	GT	●●●●	25.00	25.00	24.88	24.76	-4.29	100.00		
GUD3 GT_C	GT	●●●●	45.00	0.22	0.00	0.00	0.00	100.00		
EXT 380 DUISB	EXT	●●●●	20000.00	0.00	-98.91	-98.91	-2.07	100.00		
EXT 380 KOELN	EXT	●●●●	25000.00	0.00	-123.64	-123.64	-7.34	100.00		
Summe			45355.00	312.00	87.89	63.63	-32.78			

## Load control

The 'Last-Management - Gesamtnetz' window displays a table of load management data with columns for Last, Lastname, Pnen, Qnen, Pakt, Qakt, and Psoll. A right-hand panel shows controls for 'Last topologisch unverstärkt', 'Last deaktiviert', and 'F-Ruecknahme [%]'.

Last	Lastname	Pnen[MW]	Qnen[MVar]	Pakt[MW]	Qakt[MVar]	Psoll[%]
1	DUISB 220 ABG1	100.00	10.00	26.81	2.68	80.00
2	DUISB 220 ABG2	100.00	10.00	44.09	4.40	80.00
3	DUISB 20 ABG1	50.00	5.00	4.01	0.40	80.00
4	DUISB 20 ABG2	50.00	5.00	34.27	3.42	80.00
5	ESSEN 110 ABG3	50.00	5.00	9.82	0.96	80.00
6	ESSEN 110 ABG4	50.00	5.00	12.47	1.24	80.00
7	ESSEN 10 ABG1	20.00	1.00	4.80	0.24	80.00
8	ESSEN 10 ABG2	20.00	1.00	1.60	0.08	80.00
9	KOELN 220 ABG	100.00	10.00	65.13	6.50	75.00
10	KOELN 110 ABG2	50.00	5.00	0.00	0.00	80.00
11	KOELN 110 ABG3	50.00	5.00	30.95	3.09	80.00
12	KOELN 110 ABG4	50.00	5.00	3.51	0.35	70.00
13	KOELN 110 ABG5	50.00	5.00	3.51	0.35	70.00
14	KOELN 20 ABG1	50.00	5.00	11.69	1.17	75.00
15	MGLDB 110 ABG2	40.00	4.00	2.28	0.23	57.00
16	MGLDB 110 ABG3	40.00	4.00	0.00	0.00	80.00
17	MGLDB 20 ABG1	40.00	1.00	0.00	0.00	80.00
18	MGLDB 20 ABG4	40.00	1.00	3.20	0.08	80.00
19	REMSD 110 ABG1	20.00	1.00	1.00	0.05	5.00
20	REMSD 110 ABG2	20.00	1.00	15.02	0.75	75.00
21	REMSD 110 ABG3	20.00	1.00	10.01	0.50	50.00
22	REMSD 10 LAST	30.00	4.00	0.00	0.00	80.00
23	SOLIN 110 ABG2	50.00	3.00	20.65	1.24	75.00
24	SOLIN 110 ABG3	50.00	3.00	0.00	0.00	75.00

## Event log

The event log window displays a list of events with columns for time, event name, and description. Key events include 'GRZNRRT\_A', 'VS', and 'P\_SOLL'.

Time	Event Name	Description
32 00:01:49:681	ALM	01.03.2002
33 00:01:49:681	GT_RD	01.03.2002
34 00:01:49:682	GT_PSH	01.03.2002
35 00:01:49:682	GT_BCO	01.03.2002
36 00:01:49:682	GT_HTM	01.03.2002
37 00:01:49:682	GT_BBK	01.03.2002
38 00:01:49:682	GT_BBK	01.03.2002
39 00:00:09:999	GT	12.06.2002
40 00:00:09:999	GT	12.06.2002
41 00:00:09:999	GT	12.06.2002
42 03:43:00:136	BS	12.06.2002
43 03:43:20:159	BS	12.06.2002
44 00:09:47:323	DIM	13.06.2002
45 00:09:47:494	DIM	13.06.2002
46 00:09:50:200	HW	13.06.2002
47 00:09:50:200	HW	13.06.2002
48 00:09:50:200	VN	13.06.2002
49 00:09:50:200	VN	13.06.2002
50 00:09:50:200	DM	13.06.2002
51 00:09:50:200	PJ	13.06.2002
52 00:09:50:201	AVI	13.06.2002
53 00:09:50:201	AVI	13.06.2002

## Mesaurement recorder

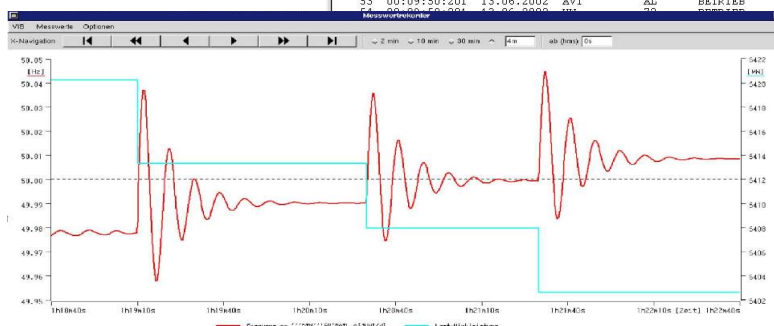


Fig. 5 Further interactive operation diagrams

**Further operational diagrams** (see Fig.5) comprise:

- **Power plant operation survey.** This format is automatically assembled when called for. It contains in one line each the operational data for all power units of a power plant group defined as a “responsibility area”. Clicking to the line, the menu to the right shows further data of the relevant power unit and provides control facilities for it.
- **Generator power diagrams** can also be called for by selecting the relevant power-unit line.
- **Event log windows** show primarily all event-texts of a “responsibility area” in chronological order. To enhance the survey, at request of the trainee filter commands (e.g. “only transformer alarms” or “only isolator-movements in substation XXX” ) can be exerted on the data. Filter commands are either pre-formulated or can be formulated ad hoc in GDL.
- **Measurand-record windows.** Beside the measurands, which appear in the switchyard diagram or power plant survey and are cyclically refreshed, a subset of measurands can be selected for recording. These measurands are then continuously stored and can be displayed in the measurand window with selectable time scale.

The measurand window can be hard-copied. It is a good habit to select for recording a set of especially expressive measurands (e.g. frequencies or maximum and minimum voltage of network islands) at the beginning of a training session and have their trajectories over the whole training period afterwards copied to the trainees for the final discussion.

Further alpha-formats, which allow a fast survey over the power system and which show also details from the Dynamic Model which are not visible to the trainees, are provided to the instructor.

## 6. Preparation of Scenarios

Having set up the process data-base and after the automatic design of the stored operational diagrams, in a third step the modelled power system must be brought to the switching-, load- and supply-state, from which the study or the next training run shall start.

As the interactive operational diagrams are already available, it is a convenient way to enter the states via these surfaces. Further, for a fast preparation of such scenarios, the PSH provides a set of powerful scenario management tools. All scenarios are saved in a set of human readable ASCII-Files, so it is possible to modify each scenario via a simple editor.

Beside the preparation of (static) start-scenarios, there is the facility to define **dynamic scenarios** which consist of a sequence of time-labelled descriptors. These sequences are stored, activated according to their time-label, entered via the Event Management and change the power-system state accordingly. In that way load changes or disturbance states growing-up during the training period can be modelled. Dynamic scenarios can also be made active on the condition of special network states or released by the instructor.

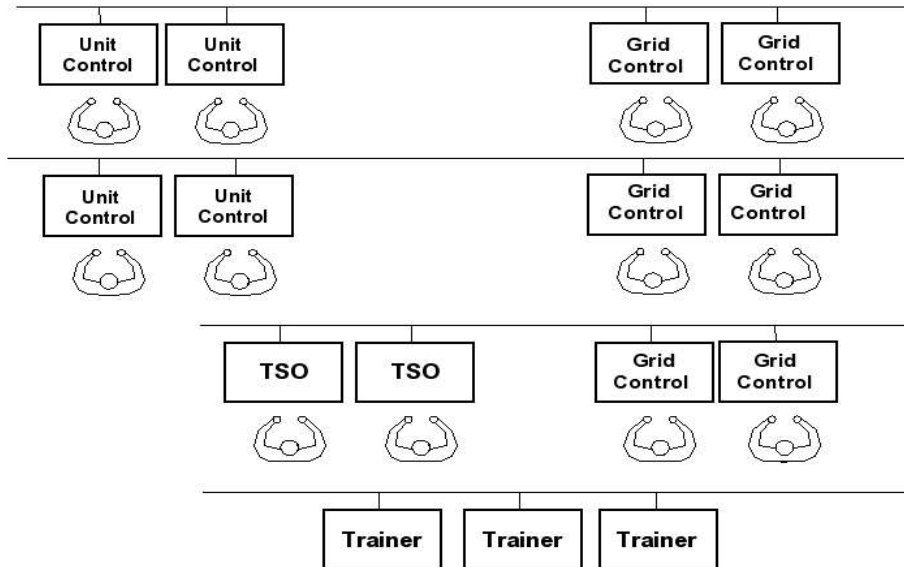
Further more it is possible to model variable load demand, and, with respect to the wind generation model, variable wind speeds for defined regions.

## 7. Operation of the DUtrain-PSH

Usually, **one** well equipped PC is applied for updating the PSH. That is: feeding in the GDL source-text and establishing the GDL process data-base, automatic design of the diagrams and storing them in the diagram data-base. This PC is later used as server for the training system.

In principle, the full program system including the Dynamic Model, can also be installed and run on this one PC with one monitor. This may be reasonable, if the simulator is only used for studies, or

for preparing the scenarios for future training sessions. In that case, the reduced computation power of one only PC may not afford real-time operation.



**Fig. 6: Typical PSH configuration**

In typical OTS operation, the PSH uses a **cluster of several LAN-linked PCs** (Fig. 6). Up to three PCs operate as servers for the Dynamic Model and for the data bases respectively. The monitors of this couple can also be used as instructor desk.

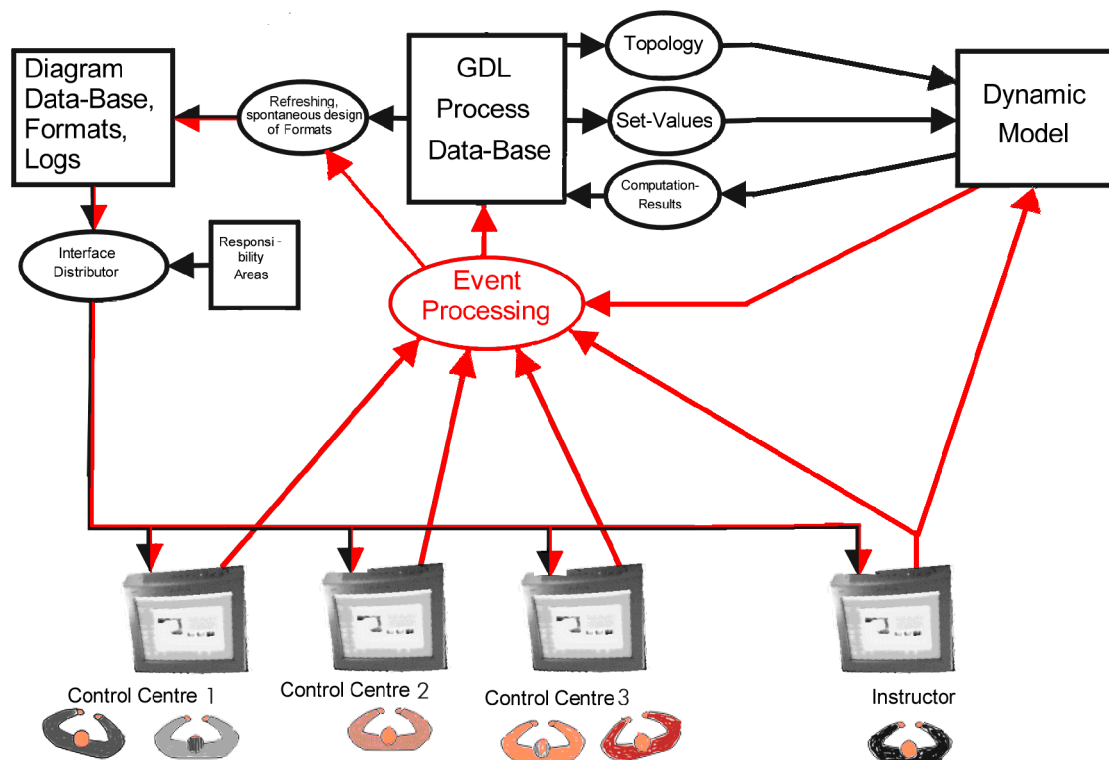
Each control-centre modelled is equipped with two PCs providing four monitors.

The PC(s) assigned to the different control-centres are linked to the servers by calling, according to Fig 6, from the respective PC

- the name assigned in the file “responsibility areas”
- the relevant surface-types.

Surfaces	Grid 380kV	Responsibility-Areas			Power Plants
		110kV A	110kV B	110kV B	
Switching	X	X	X	-	-
Loading	-	-	-	-	X
Unit-Control	-	-	-	-	X
Logs	X	X	-	X	X
Measurand Recorders	X	X	-	X	-

**Fig. 7: Definition of the control-centres by assignment of responsibility-areas and surfaces.**



**Fig. 8: Data exchange in the PSH system**

**Data processing in the PSH** applies three time-levels, two of which work in firm cycles and one asynchronously.

- A 100ms cycle is used for the frequency-model with the immediately coupled models for load rejection and frequency-recording. These processes internally run on the Dynamic Model server and exert asynchronous event-indications to the outside.
- A 5sec or 10sec time-step is used for the main-cycle of the OTS, which comprises the topology evaluation from the GDL process data-base and the transfer of the control commands to the Dynamic Model. Via load model, power unit models and power-flow, the Dynamic Model computes the new results for the continuous (measured-)values and returns them to the process data-base. Events, found e.g. by the overload protection model, are returned to the event processing .
- Asynchronous (coloured red in **Fig.8**) is the processing of switching- and setting-commands, which are entered by the training operators via the different interactive surfaces; as well as the events generated by the Dynamic Model. They are asynchronously collected and logged, then entered to the process data-base at the start of the next time-step of the main cycle.

## 8. Application

One of the main applications of the DUtrain PSH is the training of network restoration after **major disturbances (Black-outs)**. In this case, the cooperation of several or many control-centres is required. Also – what in earlier times was considered a matter of course – namely the **coordinated interplay of network- and power plant activities**, has been made problematic by market liberalisation. Major disturbances of power systems are still infrequent and cannot be initiated just

for exercise; therefore the experience of the operators in overcoming these conditions remains scarce. The DUtrain PSH possesses the facilities to

- give to the operators a faithful replica of their very power system,
- provide all the control facilities found in their control centres,
- possesses power unit models for the full operational range in normal and bypass-operation,
- present several control centres in cooperation (inter utility training).

Thus, it becomes possible to have the operators experience the performance of their proper systems in disturbed conditions.

As indicated above, the open communication between “control-centres” can be forestalled by articulating the training room with wooden walls (see **Fig. 2**) and providing a telephone connection between “control centres” only. This gives better realism to the training procedures. But, as experience shows, also sessions with open communications are useful, because in that case the operators (e.g. of the grid-control) see, how their advices are fulfilled in other (e.g. subtransmission- and power plant-) control centres and vice versa. Thus, an enhanced team-feeling is instilled.

As a matter of course, the PSH can also be used for demonstrating **smaller disturbances** and **normal operation** (e.g. fault elimination and load shifting in medium voltage networks). In these cases also learning by doing is creating experience, but a special training remains useful for the **introduction** of new personal, or when experienced operators are confronted with **new network-parts or pieces of equipment**.

The possibility to use the PSH also in **study-mode** has already been mentioned above. Contrary to commercial simulators, substation structures are mapped in full detail. Therefore one can also study whether special (e.g. emergency-) topologies are switchable at all and in which time they can be achieved. Additional need for studies arise from the integration of **large scale wind power generation** into the distribution and transmission grids. The PSH allows to study the overall system performance from the operator's point of view, especially under abnormal conditions.

A considerable advantage of the **DUtrain PSH** is its high flexibility and ease in the data-collection and amendment as well as in its adaptable hardware set-up. It is comfortably possible to produce the descriptions of network-parts of one or several utilities and to keep them up to date, to in short assemble them in the simulator according to the training-task. In that way the simulator can be employed **rotating between the most different power systems and training tasks**.

Finally, the PSH application in **university lab-courses** for "Electrical Power Systems" and "Power System Control" should be mentioned, as is practised at the Gerhard Mercator University Duisburg since long years. By these means the students are instructed with good realism in network and substation structures and their operation.

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