Available online at www.sciencedirect.com
ScienceDirect
IFAC-PapersOnLine 49-27 (2016) 195–200

# Simulation Engine for Dispatcher Training and Engineering Network Simulators

K. Máslo* , M. Kolcun**

*ČEPS, a. s.; Prague, Czech Republic
(e-mail: maslo@ceps.cz).
**Technical University of Kosice, Slovak Republic

**Abstract:** The paper presents a simulation engine for power system electromechanical transient modelling. This engine can be incorporated into a dispatcher training simulator. The same engine is used in the engineering network simulator MODES. Commands and protection models, specific for using in a dispatcher simulators are described. Rotor angle and frequency stability calculations are also presented.



*Keywords:* dispatcher training simulator, network simulator, turbine models, angle and frequency stability

## 1. INTRODUCTION

Neuman at al. (1999) introduced the network simulator MODES (Modelling of Electric power System) 17 years ago. The simulator covered a wide range of power system dynamics from electromechanical transients (several seconds) to the long-term simulation (several minutes or hours).

This paper presents the progress in the development and utilization of this tool. Since the simulation engine operates in real time or faster, it can be utilised in dispatcher training simulators. The same engine is used in the network simulator for ordinary angular and frequency stability calculations.

The following section introduces the improvements of the simulation engine named DMES (Dynamic Model of Electric power System), which is incorporated in the Dispatch Training Simulator (DTS) used by the Czech transmission system operator (CEPS).

Improvements of the steam turbine models in order to simulate a steam turbine fast valving correctly (for short-term angle stability calculations) are presented in Section 3, while section 4 deals with the island operation focusing on under-frequency load shedding.

## 2. SIMULATION ENGINE FOR DTS

The idea to use simulation engine as a dynamic linking library in a dispatcher training simulator was published for the first time in Máslo (1997). The idea was further developed in Máslo (2006). The integration of the DMES into the real Dispatcher Training Simulator (DTS) started in 2007 and the DTS is now routinely used for training of dispatchers – see Slámka (2016).

This section describes special features, which are necessary for successful integration of the simulation engine into the DTS. They are slightly different for engineering time-domain simulators used for the transmission system development and planning.

### 2.1 Generation control model

Synchronous generators play an important part in power system control. This control has hierarchical character and represents a very complex system. With some simplification, it can be divided into secondary and primary levels depicted in Fig. 1 and Fig. 2.

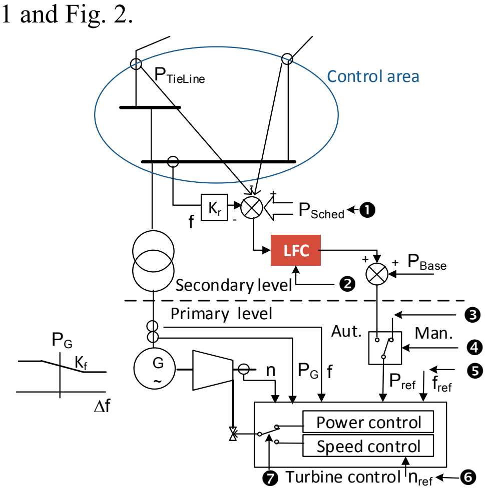


Fig. 1. Unit contribution to active power/frequency control

The primary frequency control is a decentralized function of the turbine governor and is implemented by frequency correction of power reference value $P_{ref}$. The resulting static turbine characteristic (dependence of generator output $P_G$ on frequency deviation $\Delta f$) is shown on the left side of the block scheme. The secondary control or Load Frequency Control (LFC) is a centralised automatic function that controls power generation in a control area. Its main purpose is to maintain interchange power flow P at the scheduled value $P_{Sched}$ and to restore the frequency f in case of a frequency deviation originating from the control area. P/f domain control is described in detail in Máslo and Kolcun (2014).

The turbine control may operate in two different control modes: power (or load) and speed control. In previous mechanical–hydraulic and electro–hydraulic systems both

2405-8963 © 2016, IFAC (International Federation of Automatic Control) Hosting by Elsevier Ltd. All rights reserved.
Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2016.10.682

controls worked in series, but in the digital controllers they work in parallel or alone (see Máslo et al. (2004)).

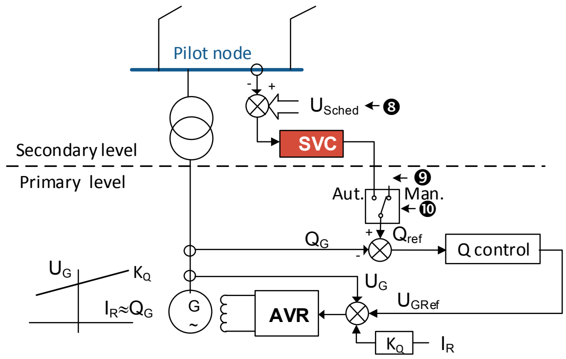


Fig. 2. Unit contribution to reactive power/voltage control

The primary voltage control is implemented by the Automatic Voltage Regulator (AVR). It initiates a fast variation in the excitation in order to control terminal voltage $U_G$. The so-called load compensation is usually used for generators operating parallel to the power grid. This function is performed by reactive current $I_R$ correction of voltage reference value $U_{GRef}$. The resulting static generator characteristic (dependence of terminal voltage $U_G$ on terminal reactive current $I_R$ or reactive power $Q_G$) is shown on the left side of the block scheme. In this case, the generator virtually controls the voltage at an external point, usually in the middle of the step-up transformer. Secondary Voltage Control (SVC) distributes reactive power among relevant generators within a given zone of the network in order to maintain scheduled voltage level $U_{Sched}$ at the pilot nodes. Q/V domain control is described in detail in Máslo and Hruška (2015).

A number of commands have been implemented in the DMES to manage units and supervisory LFC and SVC. The most important are shown symbolically as black circles in Fig. 1 and Fig. 2 and described in the following table:

**Table 1. List of the DMES commands**

| # | Meaning |
|---|---|
| ❶ | Area power balance changing |
| ❷ | LFC mode settings (P/f control, flat control, frozen) |
| ❸ | Local change of reference power |
| ❹ | Switch between remote (LFC) and manual control |
| ❺ | Reference frequency setup |
| ❻ | Reference speed setup |
| ❼ | Switching between power and speed controls |
| ❽ | Pilot node scheduled voltage changing |
| ❾ | Local change of reference power or voltage |
| ❿ | Switch between remote (SVC) and manual control |

Other commands serve for unit state control: in operation, idle operation (with nominal speed and voltage), shutdown and start up (with automatic synchronisation). A complete list of commands is in the Appendix A.

The unit model also includes basic protections with default settings: out of step, reverse power, over speed, over voltage, under voltage and others.

### *2.2 Load models*

The simulation engine enables continuous changes of active power consumption $P_{LOAD}$ in dependency on node voltage U:

$$P_{LOAD} = \frac{P_0}{(C + AU_0 + BU_0^2)}(1 + dP_{RAMP} + dP_{LS})(C + AU + BU^2) \quad (1)$$

$P_0$ and $U_0$ are the initial power consumption and voltage, A, B, C are parameters, $dP_{RAMP}$ and $dP_{LS}$ are load ramp changes (according to historical series) and due load shedding (carried out by under-frequency relays or by dispatcher interventions). A model of four stage under-frequency load shedding is also implemented in the simulation engine.

### *2.3 Protections models*

The basics of protection modelling have been published in Máslo (2008). The present simulation engine contains the following models of protections and automatics:

1. Distance relay
2. Overcurrent relay
3. Differential relay
4. Directional ground relay
5. Synchronizing device
6. Automatic reclosing
7. Bus differential relay
8. Circuit breaker failure protection.

Fig. 3 shows an arrangement of the first five models.

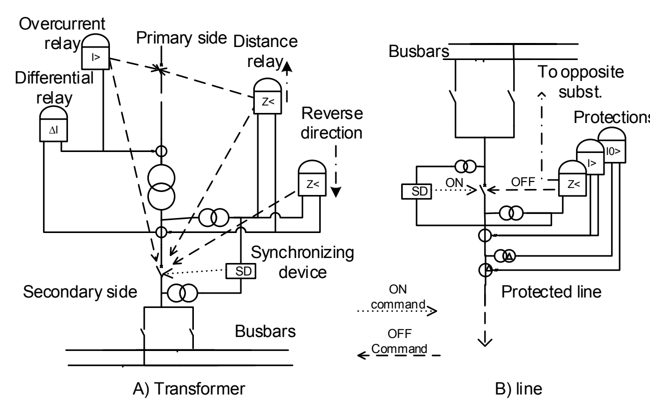


Fig. 3. Protection models for transformers and lines

For transformers (EHV/110 kV) the distance relay measures on the secondary side and usually the first and second zones are setup in the first quadrant of the complex plane and switch off the breakers on both sides. The third and fourth zones are setup in the fourth complex plane quadrant and switch off the breakers on the secondary side. For EHV lines, the distance relays are usually used, while for HV lines the overcurrent and directional ground relays are applied.

The first six models are combined into one object named feeder. Disconnector and circuit breakers are modelled as independent topological objects (branches). A more sophisticated topological object, named bay, has been prepared and published by Máslo and Eickman (2014).

Transformers can be equipped by on-load tap-changers (OLTC).