# Principles of Computer Aided Modeling and Simulation

- **Traditional approach: "ad hoc" model**
  - **these models are difficult to be handled for those who aren't model specialists**
  - **modifications are not easy and it's difficult to build new models from already functioning patterns**

# Classification of CAMS codes

- **MMS, RETRAN codes oriented to user with few concepts about programs and models**
  - the user must only give some alphanumeric data to define topology and data
  - there is little flexibility: it's difficult modify the models
- **SICLE: oriented to users having greater knowledge of informatics and models**
  - more flexible
  - the user must write a FORTRAN code to put together and running the simulator
- **LEGO: oriented to users of whatsoever degree of knowledge on programs and models**
  - the topology may be constructed giving only alphanumerical data but it's also possible, with a few notions of FORTRAN programming, create a new module

# THE LEGO CODE

- Completely developed at CRA (ENEL) in 1981
- Modular code for the solution of both steady state and transient equations)
- Easy topology construction and data insertion
- Wide library of tested modules ranging from nuclear to conventional applications

# LEGO and EDF

- The LEGO code is actually in use at EDF-SEPTEN for studying the general functioning of the 1300 MW and 1500 MW RNR

- It has also been introduced by EDF - DER in the general solver SIMLAB

# LEGO structure

- **MODULES LIBRARY**
  - contains self consistent mathematical models of elementary processes and components
- **MASTER PROGRAM**
  - allows the user to set up an overall plant by assembling elementary modules and thereafter solves the whole resulting system as a set of non-linear algebraic and differential equations

# LEGO LIBRARY

- The LEGO code has been succesfully used in the years in many fields of applications besides the ones for which it had been created. Among them:
  - power system
  - robotics
  - fuel cells
  - iron strip mill plants
- The code LEGO has simulated many types of processes, characterized by different equations and different time constants

# VALIDATIONS OF LEGO LIBRARY

- Validation of a UP 320 MW once-through plant model with regard to experimental tests
- Validation of a PWR 900 MW nuclear plant using EDF experimental test data
- Validation of a BWR 1000 MW nuclear plant with respect to other calculation codes (RETRAN, REDY)
- Validation of the LEGO drift flux model for a two phase flow channel of a steam generator with respect to RELAP5 mod 3 and MMS codes

# USER

MODEL TOPOLOGICAL DATA

PHISICAL AND GEOMETRICAL DATA

USER'S FUNCTIONS

USER'S MODULES

# LEGO PACKAGE

MASTER PROGRAM

INTERCONNECTION SUBPROGRAMS

MODULES LIBRARY

STEAM WATER PROPERTIES SUBROUTINES

# APPLICATION

MODEL BUILDING

STEADY STATE COMPUTATION

TRANSIENT SIMULATION

GRAPHIC RESULTS PRESENTATION

Enel

# Typical assets of the LEGO package:

- **MODULARITY**
  - » the user can set up an overall plant model by using a limited set of modules
- **FLEXIBILITY**
  - » there is a tool (NEWMOD) that allows a fast and simple creation of a new module also by users having only base concepts on FORTRAN programming
- **RELIABILITY**
  - » all the numerical algorithms are placed in the "master program" and can solve any large scale non-linear algebraic and differential system, in a centralized way.

# What's a module

- It's a piece of code (i.e. a group of routines) which define the mathematical model of a plant component or a part of a process.

- The model is independent from geometrical dimensions, from the operating range (pressures, flow..) and from other parameters such as friction coefficients, thermal exchangecoefficients, etc)

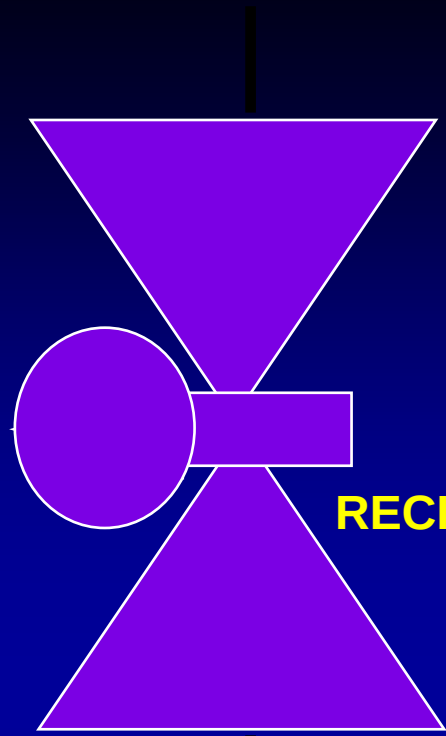
# Typical thermohydraulics modules

- valves
- pumps
- pipes
- turbine stage
- part of an exchanger (water/steam side)
- part of an exchanger (flue side)
- tanks
- etc

# TOPOLOGY

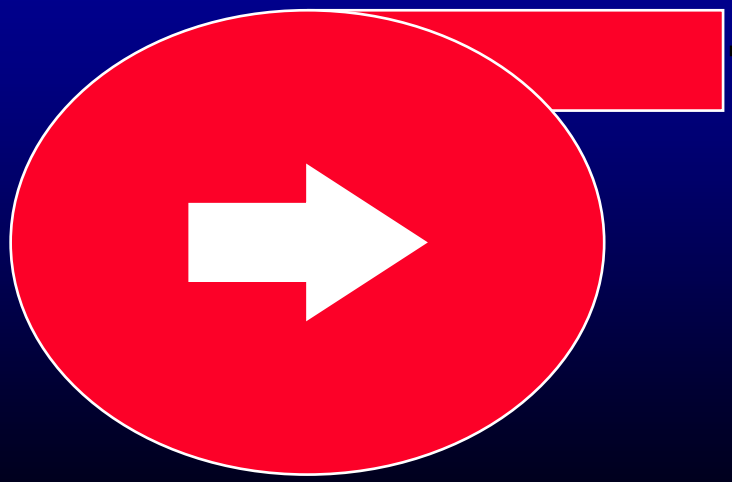
- A **Block** is a single instance of a module
- Instance names are given when model is created and must be unique in a model
- The Block name is the module name followed by the instance name (8 char.)
- Variables are classified as output or input
- Block variables names (8 char.) are formed by letting block name follow module variable name
- Connections between two blocks are made by means of their variables
- An input variable of a block connected to an output variable of another block assumes its name

# CONNECTION BETWEEN TWO LEGO MODULES



VRIC
RECIRCULATION VALVE

TPAL
FEED TURBOPUMP

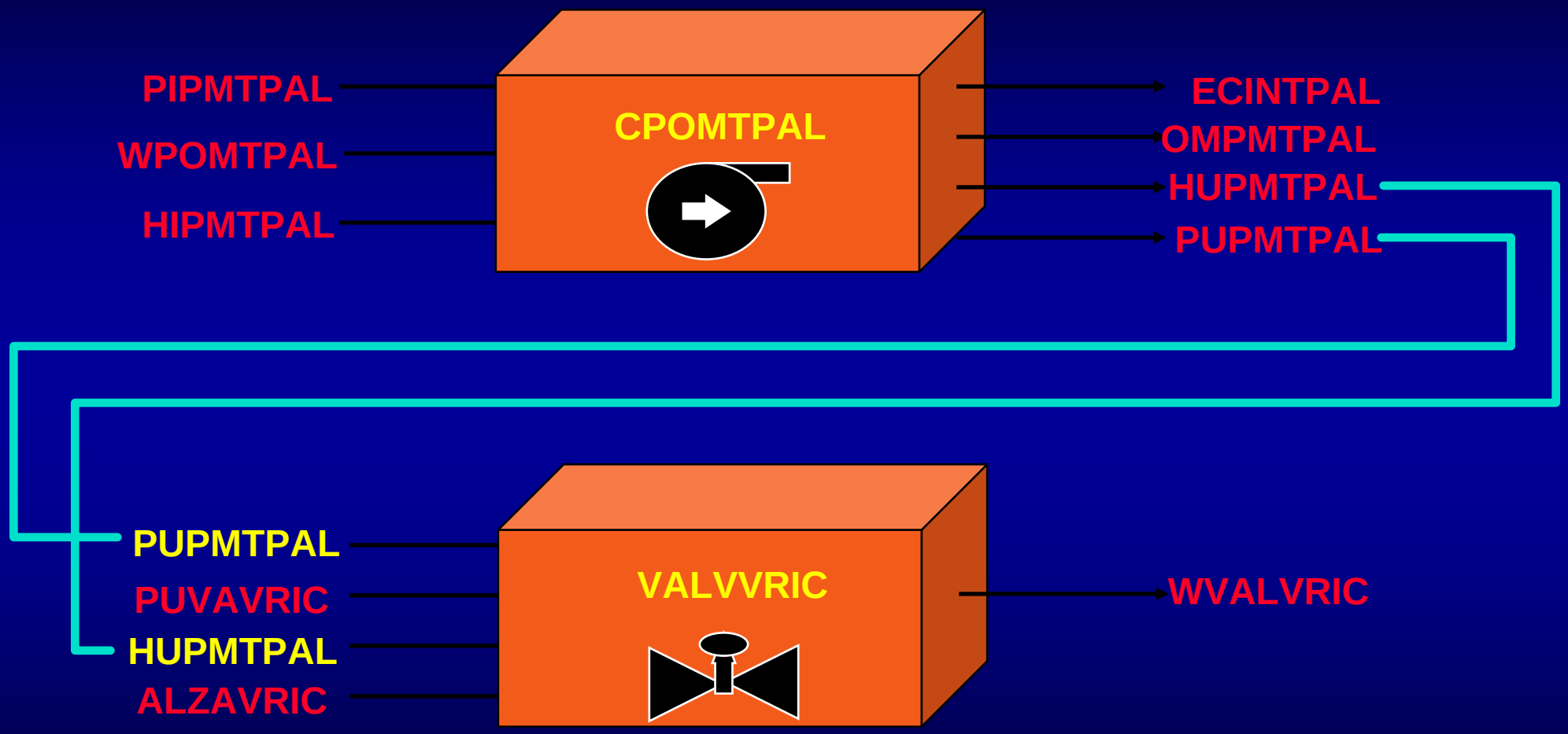


PIPMTPAL
WPOMTPAL
HIPMTPAL
CPOMTPAL
ECINTPAL
OMPMTPAL
HUPMTPAL
PUPMTPAL

PIVAVRIC
PUVAVRIC
HVALVRIC
ALZAVRIC
VALVVRIC
WVALVRIC

```
****
CPOM       BLOCCO (TPAL) - turbopompa alimento
VALV       BLOCCO (VRIC) - valvola di ricircolo
****
IMPIANTO
****
CPOMTPAL   BL.-TPAL- **** MODULO CPOM - turbopompa alimento
ECINTPAL   --US-- energia cinetica palettatura
OMPMTPAL   --UA-- velocita' angolare pompa
HUPMTPAL   --UA-- entalpia fluido uscita
PUPMTPAL   --UA-- pressione fluido uscita
PIPMTPAL   --IN-- pressione fluido ingresso
WPOMTPAL   --IN-- portata in massa fluido
HIPMTPAL   --IN-- entalpia ingresso
****
****
VALVVRIC   BL.-VRIC- **** MODULO VALV - valvola di ricircolo
WVALVRIC   --UA-- portata valvola
PIVAVRIC   --IN-- pressione ingresso
PUVAVRIC   --IN-- pressione uscita
HVALVRIC   --IN-- entalpia monte-valle
ALZAVRIC   --IN-- alzata valvola
****
****       >>>>>>INGRESSI DI TUTTI I MODULI<<<<<<
PIPMTPAL   --IN-- pressione fluido ingresso
WPOMTPAL   --IN-- portata in massa fluido
HIPMTPAL   --IN-- entalpia ingresso
PIVAVRIC   --IN-- pressione ingresso
PUVAVRIC   --IN-- pressione uscita
HVALVRIC   --IN-- entalpia monte-valle
ALZAVRIC   --IN-- alzata valvola
```

**f01.dat**
**before modules conn**

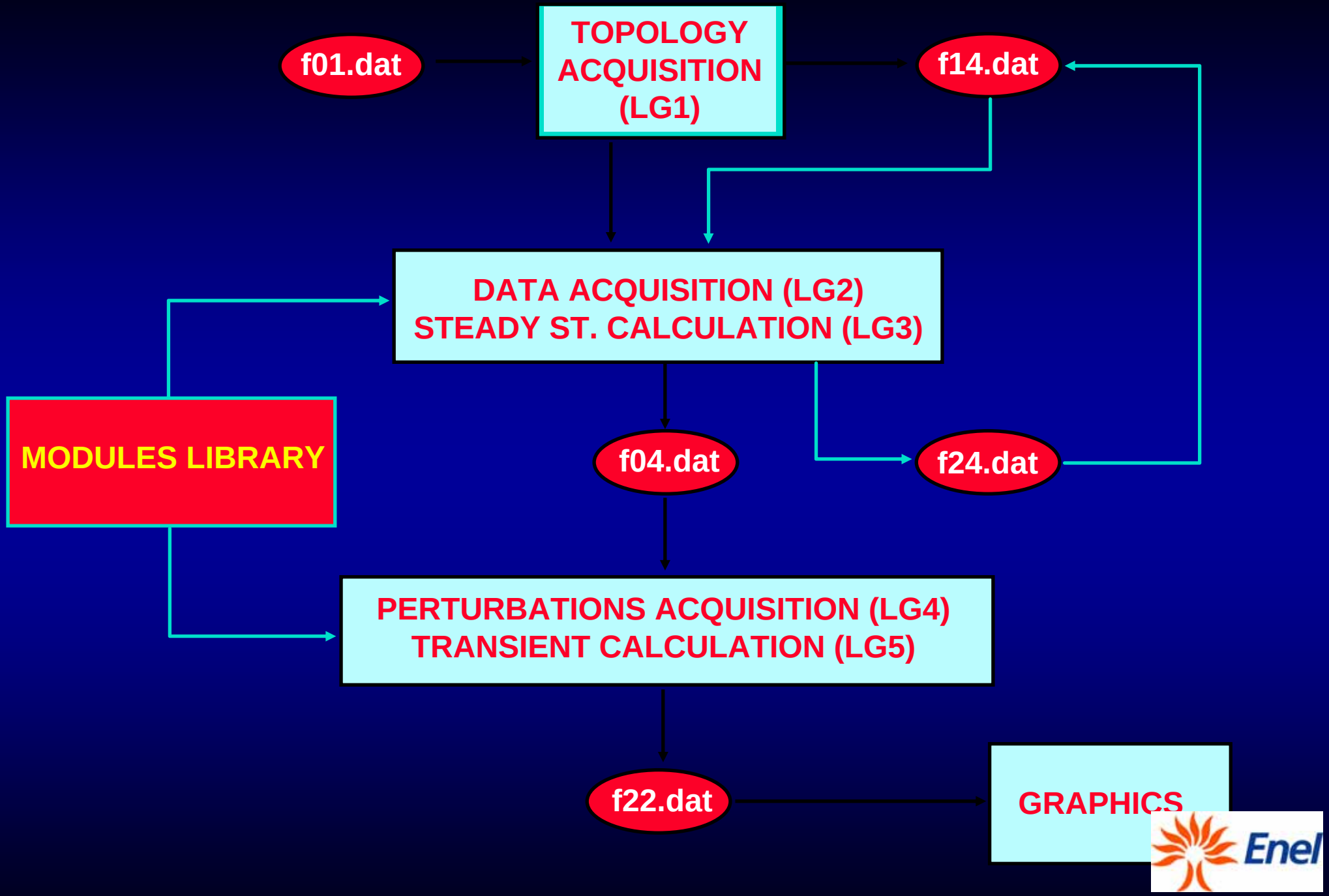

PIPMTPAL
WPOMTPAL
HIPMTPAL
CPOMTPAL
ECINTPAL
OMPMTPAL
HUPMTPAL
PUPMTPAL
PUPMTPAL
PUVAVRIC
HUPMTPAL
ALZAVRIC
VALVVRIC
WVALVRIC

```
****
CPOM       BLOCCO (TPAL) - turbopompa alimento
VALV       BLOCCO (VRIC) - valvola di ricircolo
****
IMPIANTO
****
CPOMTPAL   BL.-TPAL- **** MODULO CPOM - turbopompa alimento
ECINTPAL   --US-- energia cinetica palettatura
OMPMTPAL   --UA-- velocita' angolare pompa
HUPMTPAL   --UA-- entalpia fluido uscita
PUPMTPAL   --UA-- pressione fluido uscita
PIPMTPAL   --IN-- pressione fluido ingresso
WPOMTPAL   --IN-- portata in massa fluido
HIPMTPAL   --IN-- entalpia ingresso
****
****
VALVVRIC   BL.-VRIC- **** MODULO VALV - valvola di ricircolo
WVALVRIC   --UA-- portata valvola
PUPMTPAL   --UA-- pressione fluido uscita
PUVAVRIC   --IN-- pressione uscita
HUPMTPAL   --UA-- entalpia fluido uscita
ALZAVRIC   --IN-- alzata valvola
****
****       >>>>>>INGRESSI DI TUTTI I MODULI<<<<<<
PIPMTPAL   --IN-- pressione fluido ingresso
WPOMTPAL   --IN-- portata in massa fluido
HIPMTPAL   --IN-- entalpia ingresso
PUVAVRIC   --IN-- pressione uscita
ALZAVRIC   --IN-- alzata valvola
****
PIVAVRIC   --CO-- pressione ingresso
HVALVRIC   --CO-- entalpia monte-valle
```

**f01.dat**
**after modules conn**

```
*LG*NOME IMPIANTO =IMPIANTO
*LG*DATI DI NORMALIZZAZIONE P0=100.E5*H0=1.E+06*W0=100.  *T0=1.E+03*R0=1.E+02*
*LG*                        L0=1.E+01*V0=5.E+01*DP0=1.E+05*
*LG*CONDIZIONI INIZIALI VARIABILI DEL SISTEMA (MKS)
  1 ECINTPAL =.50000E+06*BL.(CPOMTPAL)=NOTO* energia cinetica pompa
  2 OMPMTPAL =311.5     *BL.(CPOMTPAL)=    * velocita' angolare pompa
  3 HUPMTPAL =.35530E+04*BL.(CPOMTPAL)=    * entalpia uscita pompa
  4 PUPMTPAL =.60000E+07*BL.(CPOMTPAL)=    * pressione uscita pompa
  5 WVALVRIC =218.25    *BL.(VALVVRIC)=    * portata valvola
*LG*CONDIZIONI INIZIALI VARIABILI DI INGRESSO
  1 PIPMTPAL =.51200E+07*BL.(CPOMTPAL)=NOTO* pressione ingresso pompa
  2 HIPMTPAL =.32240E+04*BL.(CPOMTPAL)=    * entalpia ingresso pompa
  4 PIVAVRIC =.50000E+07*BL.(VALVVRIC)=NOTO* pressione ingresso valvola
  5 PUVAVRIC =.48000E+07*BL.(VALVVRIC)=NOTO* pressione uscita valvola
  6 HVALVRIC =.31650E+04*BL.(VALVVRIC)=NOTO* entalpia monte-valle valvola
  7 ALZAVRIC =.6        *BL.(VALVVRIC)=NOTO* alzata valvola
*LG*DATI FISICI E GEOMETRICI DEL SISTEMA SUDDIVISI A BLOCCHI
*LG*DATI DEL BLOCCO CPOMTPAL  MODULO CPOM -  pompa alimento
    TYP      =1.        *    INER     =          *    QVNOM    =0.01666666*
    OMNOM    =311.5     *    DPNOM    =55.72e5   *    POTN     =140.6e3   *
    DENS.    =914.      *    N.GIRAN. =1.        *    VALV INT =0.        *
*LG*DATI DEL BLOCCO VALVVRIC  MODULO VALV -  valvola ricircolo
*   DATI VALVOLA (COD. = IDENTIFICATORE PER LA SCELTA DEL MODELLO)
    ALFA     =          *    CFA      =          *    COD.     =1.        *
*   DATI RELATIVI ALLA CAPACITA  DI SCARICO
    CVA      =          *    PORTATA  =2.285     *    P1 MONTE =62.5e5    *
    P2 VALLE =5.3e5     *    ENTALPIA =0.648e6   *    CORSA    =0.8       *
*   DATI RELATIVI ALLA VALVOLA DI NON RITORNO
    DP. APER =0.2e5     *    DP. CHIU =0.1e5     *
*LG*EOF
```

f14.d
data exa


f01.dat
TOPOLOGY ACQUISITION (LG1)
f14.dat
DATA ACQUISITION (LG2)
STEADY ST. CALCULATION (LG3)
MODULES LIBRARY
f04.dat
f24.dat
PERTURBATIONS ACQUISITION (LG4)
TRANSIENT CALCULATION (LG5)
f22.dat
GRAPHICS
Enel