O PROBLEMA DO FLUXO DE POTÊNCIA

MATPOWER

Adaptação do material criado por Carolina Durce,
em 2010, para a disciplina TE158.

O que é o MATPOWER

- Pacote gratuito de arquivos tipo .m do MATLAB utilizado para solucionar fluxo de potência e fluxo de potência ótimo

- Ferramenta de simulação de sistema elétricos de potência para pesquisadores e educadores de fácil uso, entendimento e modificação.

- Conjunto de funções que podem ser executados a partir de linha de comando do MATLAB ou incluir em seus próprios programas

- Desenvolvido por pesquisadores e educadores da Universidade de Cornell, em Ithaca, NY.

O que o MATPOWER faz

- Fluxo de Potência DC (linearizado)
- Fluxo de Potência AC (não-linearizado)
  - Newton
  - Desacoplado rápido XB
  - Desacoplado rápido BX
  - Gauss-Seidel

- Fluxo de Potência Ótimo DC (linearizado)
- Fluxo de Potência Ótimo AC (não-linearizado)

INSTALAÇÃO

- **Website MATPOWER**

  http://www.pserc.cornell.edu/matpower/

- **Download → matpower6.0**
- **Colocar na pasta MATLAB**
- **Abrir o MATLAB**
- **Adicionar a pasta matpower6.0 ao path do MATLAB**
  - **Clicar com o botão direito em matpower6.0**
  - **'Add to path' - 'Selected folders and subfolders‘**
- `test_matpower`

SIMULAÇÃO

- 1º Preparar os dados de entrada → parâmetros relevantes do sistema de potência

- 2º Chamar a função para executar a simulação

- 3º Visualizar e acessar os resultados
  - Impressão na tela
  - Salvo em estruturas de saída de dados ou arquivos.

DADOS DE ENTRADA

Table D-17: Small Test Cases

name	description
case4gs	4-bus example case from Grainger & Stevenson
case5	modified 5-bus PJM example case from Rui Bo
case6ww	6-bus example case from Wood & Wollenberg
case9	9-bus example case from Chow
case9Q	case9 with reactive power costs
case9target	modified case9, target for example continuation power flow
case14	IEEE 14-bus case
case24_ieee_rts	IEEE RTS 24-bus case
case30	30-bus case, based on IEEE 30-bus case
case_ieee30	IEEE 30-bus case
case30pwl	case30 with piecewise linear costs
case30Q	case30 with reactive power costs
case33bw	33-bus radial distribution system from Baran and Wu
case39	39-bus New England case
case57	IEEE 57-bus case
case118	IEEE 118-bus case
case145	IEEE 145-bus case, 50 generator dynamic test case
case_illinois200	Synthetic 200 bus Illinois case*
case300	IEEE 300-bus case

* Please cite reference [31] when publishing results based on this data.

DADOS DE ENTRADA

Table B-1: Bus Data (mpc.bus)

name	column	description
BUS_I	1	bus number (positive integer)
BUS_TYPE	2	bus type (1 = PQ, 2 = PV, 3 = ref, 4 = isolated)
PD	3	real power demand (MW)
QD	4	reactive power demand (MVAr)
GS	5	shunt conductance (MW demanded at $V = 1.0$ p.u.)
BS	6	shunt susceptance (MVAr injected at $V = 1.0$ p.u.)
BUS_AREA	7	area number (positive integer)
VM	8	voltage magnitude (p.u.)
VA	9	voltage angle (degrees)
BASE_KV	10	base voltage (kV)
ZONE	11	loss zone (positive integer)
VMAX	12	maximum voltage magnitude (p.u.)
VMIN	13	minimum voltage magnitude (p.u.)
LAM_P†	14	Lagrange multiplier on real power mismatch (u/MW)
LAM_Q†	15	Lagrange multiplier on reactive power mismatch (u/MVAr)
MU_VMAX†	16	Kuhn-Tucker multiplier on upper voltage limit (u/p.u.)
MU_VMIN†	17	Kuhn-Tucker multiplier on lower voltage limit (u/p.u.)

† Included in OPF output, typically not included (or ignored) in input matrix. Here we assume the objective function has units u.

Table B-2: Generator Data (mpc.gen)

name	column	description
GEN_BUS	1	bus number
PG	2	real power output (MW)
QG	3	reactive power output (MVAr)
QMAX	4	maximum reactive power output (MVAr)
QMIN	5	minimum reactive power output (MVAr)
VG[‡]	6	voltage magnitude setpoint (p.u.)
MBASE	7	total MVA base of machine, defaults to baseMVA
GEN_STATUS	8	machine status, > 0 = machine in-service ≤ 0 = machine out-of-service
PMAX	9	maximum real power output (MW)
PMIN	10	minimum real power output (MW)
PC1[*]	11	lower real power output of PQ capability curve (MW)
PC2[*]	12	upper real power output of PQ capability curve (MW)
QC1MIN[*]	13	minimum reactive power output at PC1 (MVAr)
QC1MAX[*]	14	maximum reactive power output at PC1 (MVAr)
QC2MIN[*]	15	minimum reactive power output at PC2 (MVAr)
QC2MAX[*]	16	maximum reactive power output at PC2 (MVAr)
RAMP_AGC[*]	17	ramp rate for load following/AGC (MW/min)
RAMP_10[*]	18	ramp rate for 10 minute reserves (MW)
RAMP_30[*]	19	ramp rate for 30 minute reserves (MW)
RAMP_Q[*]	20	ramp rate for reactive power (2 sec timescale) (MVAr/min)
APF[*]	21	area participation factor
MU_PMAX[†]	22	Kuhn-Tucker multiplier on upper P_g limit (u/MW)
MU_PMIN[†]	23	Kuhn-Tucker multiplier on lower P_g limit (u/MW)
MU_QMAX[†]	24	Kuhn-Tucker multiplier on upper Q_g limit (u/MVAr)
MU_QMIN[†]	25	Kuhn-Tucker multiplier on lower Q_g limit (u/MVAr)

[*] Not included in version 1 case format.

[†] Included in OPF output, typically not included (or ignored) in input matrix. Here we assume the objective function has units u.

[‡] Used to determine voltage setpoint for optimal power flow only if opf.use_vg option is non-zero (0 by default). Otherwise generator voltage range is determined by limits set for corresponding bus in bus matrix.

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Table B-3: Branch Data (mpc.branch)

name	column	description
F_BUS	1	"from" bus number
T_BUS	2	"to" bus number
BR_R	3	resistance (p.u.)
BR_X	4	reactance (p.u.)
BR_B	5	total line charging susceptance (p.u.)
RATE_A	6	MVA rating A (long term rating), set to 0 for unlimited
RATE_B	7	MVA rating B (short term rating), set to 0 for unlimited
RATE_C	8	MVA rating C (emergency rating), set to 0 for unlimited
TAP	9	transformer off nominal turns ratio, (taps at "from" bus, impedance at "to" bus, i.e. if $r = x = b = 0$, $tap = \frac{\|V_f\|}{\|V_t\|}$)
SHIFT	10	transformer phase shift angle (degrees), positive $\Rightarrow$ delay
BR_STATUS	11	initial branch status, 1 = in-service, 0 = out-of-service
ANGMIN*	12	minimum angle difference, $\theta_f - \theta_t$ (degrees)
ANGMAX*	13	maximum angle difference, $\theta_f - \theta_t$ (degrees)
PF†	14	real power injected at "from" bus end (MW)
QF†	15	reactive power injected at "from" bus end (MVAr)
PT†	16	real power injected at "to" bus end (MW)
QT†	17	reactive power injected at "to" bus end (MVAr)
MU_SF‡	18	Kuhn-Tucker multiplier on MVA limit at "from" bus (u/MVA)
MU_ST‡	19	Kuhn-Tucker multiplier on MVA limit at "to" bus (u/MVA)
MU_ANGMIN‡	20	Kuhn-Tucker multiplier lower angle difference limit (u/degree)
MU_ANGMAX‡	21	Kuhn-Tucker multiplier upper angle difference limit (u/degree)

* Not included in version 1 case format. The voltage angle difference is taken to be unbounded below if ANGMIN < -360 and unbounded above if ANGMAX > 360. If both parameters are zero, the voltage angle difference is unconstrained.

† Included in power flow and OPF output, ignored on input.

‡ Included in OPF output, typically not included (or ignored) in input matrix. Here we assume the objective function has units u.

DADOS DE ENTRADA

```
%% bus data
%bus_i type Pd      Qd      Gs  Bs  area    Vm      Va      baseKV  zone    Vmax    Vmin
mpc.bus = [
    1   3   0       0       0   0   1       1.06    0       0       1       1.06    0.94;
    2   2   21.7    12.7    0   0   1       1.045   -4.98   0       1       1.06    0.94;
    3   2   94.2    19      0   0   1       1.01    -12.72  0       1       1.06    0.94;
    4   1   47.8    -3.9    0   0   1       1.019   -10.33  0       1       1.06    0.94;
    5   1   7.6     1.6     0   0   1       1.02    -8.78   0       1       1.06    0.94;
    6   2   11.2    7.5     0   0   1       1.07    -14.22  0       1       1.06    0.94;
    7   1   0       0       0   0   1       1.062   -13.37  0       1       1.06    0.94;
    8   2   0       0       0   0   1       1.09    -13.36  0       1       1.06    0.94;
    9   1   29.5    16.6    0   19  1       1.056   -14.94  0       1       1.06    0.94;
    10  1   9       5.8     0   0   1       1.051   -15.1   0       1       1.06    0.94;
    11  1   3.5     1.8     0   0   1       1.057   -14.79  0       1       1.06    0.94;
    12  1   6.1     1.6     0   0   1       1.055   -15.07  0       1       1.06    0.94;
    13  1   13.5    5.8     0   0   1       1.05    -15.16  0       1       1.06    0.94;
    14  1   14.9    5       0   0   1       1.036   -16.04  0       1       1.06    0.94;
];
```

DADOS DE ENTRADA

```
%% generator data
%    bus Pg       Qg       Qmax     Qmin     Vg
mpc.gen = [
     1   232.4    -16.9    10       0        1.06
     2   40       42.4     50       -40      1.045
     3   0        23.4     40       0        1.01
     6   0        12.2     24       -6       1.07
     8   0        17.4     24       -6       1.09
];
```

DADOS DE ENTRADA

```
%% branch data
%    fbus tbus    r        x        b
mpc.branch = [
     1    2       0.01938 0.05917 0.0528
     1    5       0.05403 0.22304 0.0492
     2    3       0.04699 0.19797 0.0438
     2    4       0.05811 0.17632 0.034
     2    5       0.05695 0.17388 0.0346
     3    4       0.06701 0.17103 0.0128
     4    5       0.01335 0.04211 0
     4    7       0       0.20912 0
     4    9       0       0.55618 0
     5    6       0       0.25202 0
     6    11      0.09498 0.1989  0
     6    12      0.12291 0.25581 0
     6    13      0.06615 0.13027 0
     7    8       0       0.17615 0
     7    9       0       0.11001 0
     9    10      0.03181 0.0845  0
     9    14      0.12711 0.27038 0
     10   11      0.08205 0.19207 0
     12   13      0.22092 0.19988 0
     13   14      0.17093 0.34802 0
];
```

OPÇÕES DE EXECUÇÃO

Table 4-2: Power Flow Options

name	default	description
model	'AC'	AC vs. DC modeling for power flow and OPF formulation 'AC' – use AC formulation and corresponding alg options 'DC' – use DC formulation and corresponding alg options
pf.alg	'NR'	AC power flow algorithm: 'NR' – Newtons's method 'FDXB' – Fast-Decoupled (XB version) 'FDBX' – Fast-Decouple (BX version) 'GS' – Gauss-Seidel
pf.tol	10^{-8}	termination tolerance on per unit P and Q dispatch
pf.nr.max_it	10	maximum number of iterations for Newton's method
pf.fd.max_it	30	maximum number of iterations for fast-decoupled method
pf.gs.max_it	1000	maximum number of iterations for Gauss-Seidel method
pf.enforce_q_lims	0	enforce gen reactive power limits at expense of $\|V_m\|$ 0 – do *not* enforce limits 1 – enforce limits, simultaneous bus type conversion 2 – enforce limits, one-at-a-time bus type conversion

OPÇÕES PARA SAÍDA DE DADOS

Table 4-3: Power Flow Output Options

name	default	description
verbose	1	amount of progress info to be printed 0 – print no progress info 1 – print a little progress info 2 – print a lot of progress info 3 – print all progress info
out.all	-1	controls pretty-printing of results -1 – individual flags control what is printed 0 – do *not* print anything[†] 1 – print everything[†]
out.sys_sum	1	print system summary (0 or 1)
out.area_sum	0	print area summaries (0 or 1)
out.bus	1	print bus detail, includes per bus gen info (0 or 1)
out.branch	1	print branch detail (0 or 1)
out.gen	0	print generator detail (0 or 1)
out.force	0	print results even if success flag = 0 (0 or 1)
out.suppress_detail	-1	suppress all output but system summary -1 – suppress details for large systems (> 500 buses) 0 – do *not* suppress any output specified by other flags 1 – suppress all output except system summary section[†]

[†] Overrides individual flags, but (in the case of out.suppress_detail) not out.all = 1.

EXECUTAR E RESULTADOS

Table D-2: Top-Level Simulation Functions

name	description
runpf	power flow†
runcpf	AC continuation power flow
runopf	optimal power flow†
runuopf	optimal power flow with unit-decommitment†
rundcpf	DC power flow‡
rundcopf	DC optimal power flow‡
runduopf	DC optimal power flow with unit-decommitment‡
runopf_w_res	optimal power flow with fixed reserve requirements†
most	MOST, MATPOWER Optimal Scheduling Tool ‡

† Uses AC model by default.
‡ Simple wrapper function to set option to use DC model before calling the corresponding general function above.
‡ MOST and its supporting files and functions in the most/ sub-directory are documented in the MOST User's Manual and listed in its Appendix A.

- runpf('case14') → AC
- rundcpf('case14') → DC

RESULTADOS

Table 4-1: Power Flow Results

name	description
`results.success`	success flag, 1 = succeeded, 0 = failed
`results.et`	computation time required for solution
`results.iterations`	number of iterations required for solution
`results.order`	see `ext2int` help for details on this field
`results.bus(:, VM)`†	bus voltage magnitudes
`results.bus(:, VA)`	bus voltage angles
`results.gen(:, PG)`	generator real power injections
`results.gen(:, QG)`†	generator reactive power injections
`results.branch(:, PF)`	real power injected into "from" end of branch
`results.branch(:, PT)`	real power injected into "to" end of branch
`results.branch(:, QF)`†	reactive power injected into "from" end of branch
`results.branch(:, QT)`†	reactive power injected into "to" end of branch

† AC power flow only.

EXEMPLO

```
>> mpc = loadcase(casefilename);
```

```
>> runpf('case9');
```

```
>> define_constants;
>> mpc = loadcase('case30');
>> mpc.bus(2, PD) = 30;
>> runopf(mpc);
```

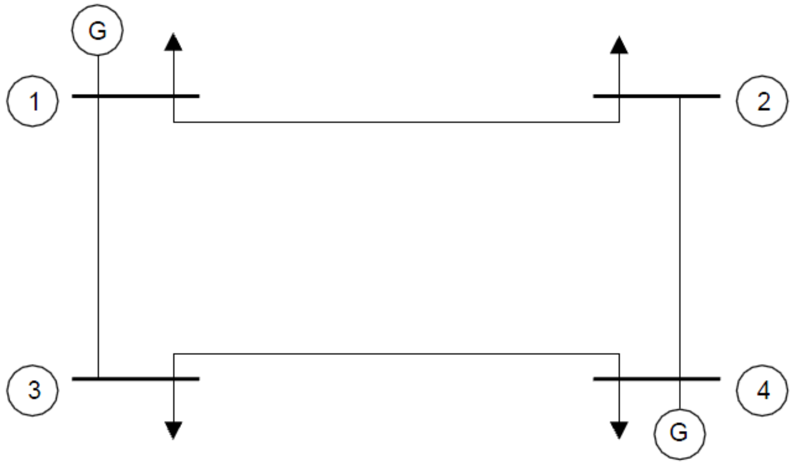
EXEMPLO

```
>> mpopt = mpoption('pf.alg', 'FDXB', 'verbose', 2, 'out.all', 0);
>> results = runpf('case300', mpopt);
```

```
>> mpopt = mpoption(mpopt, 'verbose', 0);
>> results = runpf('case300', mpopt);
```

```
>> help mpoption
```

EXERCÍCIO - 4 barras HAFFNER



Linha	Impedância série	
	r [pu]	x [pu]
1–2	0,01008	0,05040
1–3	0,00744	0,03720
2–4	0,00744	0,03720
3–4	0,01272	0,06360

Barra	V [pu]	θ [graus]	Geração		Carga	
			P [MW]	Q [Mvar]	P [MW]	Q [Mvar]
1	1,00	0	–	–	50	30,99
2	–	–	0	0	170	105,35
3	–	–	0	0	200	123,94
4	1,02	–	318	–	80	49,58

RESPOSTA:

$$\begin{bmatrix} \theta_2 \\ \theta_3 \\ \theta_4 \end{bmatrix} = \begin{bmatrix} -0{,}0185\text{ rad} \\ -0{,}0355\text{ rad} \\ 0{,}0311\text{ rad} \end{bmatrix} = \begin{bmatrix} -1{,}0590^\circ \\ -2{,}0320^\circ \\ 1{,}7830^\circ \end{bmatrix}$$