

FAULT IDENTIFICATIONS OF WIND TURBINE SYSTEM

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Abstract :- Small wind energy conversion systems are becoming increasingly popular as the demand for standalone renewable electricity generation grows globally. To accomplish the goal of small size and light weight with an, extra-low speed for direct coupling, the double circuit structure is suitable. The increasing penetration of renewable generation poses a challenge to the power system operator's task of balancing demand with generation due to the increased inter-temporal variability and uncertainty from renewable. Recently major system operators have been testing approaches to managing inter-temporal ramping requirement. In this paper we propose a robust optimization based economic dispatch model for ensuring adequate system ramp capability. The proposed model is critically assessed with the ramp product which is currently under consideration by several system operators. We conduct theoretical assessment based on a proposed lack-of ramp Comprehensive experimental tests were conducted to verify the theoretical predictions. A good agreement between the theoretical work and testing results was achieved. For a given application, the result provide an indication of advantage of better performances, reduced size and weight, and overall a best suited transmission line.

I. INTRODUCTION

The increasing penetration of renewable resources such as wind and solar poses a challenge to the goal of the Independent System Operators (ISOs) to manage the power system with a reliable and cost effective approach. Due to the limited control over the output of renewable resources as well as associated forecast errors the ISOs will have to deal with an increasing amount of uncertainty and variability in the system [1].

One significant issue is the temporary price spikes experienced by many ISOs in the real time electricity market due to shortages attributed to a lack of system ramp capability [2]. The main causes of these shortages include variability of load, scheduled interchanges and non-controllable generation resources (primarily wind) as well as uncertainty associated with short term forecasts. Due to the physical limitations on ramp rates generators are unable to respond effectively to these price spikes. The current practices to deal with ramp shortages include increasing reserve margins, starting fast-start units (such as gas turbines) and out of market dispatch methods that involve operator action. However, these approaches are usually high cost or create some market distortion. It is important for ISOs to have *additional flexibility* for dispatchable generation resources through the market clearing process. The Security Constrained Economic Dispatch (SCED) decision needs to be robust to the uncertainties so that the critical system power balance requirement is not violated.

In recent years, robust optimization has attracted significant interest as a framework for optimization under uncertainty, led by the work [3–7]. The approach has several attractive modeling and computational advantages. First, it uses a deterministic set-based method to model parameter uncertainty. This method requires only moderate amount of information, such as the support and moments, of the underlying uncertainty. At the same time, it provides the flexibility to incorporate more detailed information. There is also a deep connection between uncertainty sets and risk theory [8]. The work in [9] uses this approach to devise a bidding strategy for a virtual power plant consisting of wind generation and energy storage. Second, the robust optimization approach yields a solution that immunizes against all realizations of uncertainty data within the uncertainty sets, rather than a finite number of sample scenarios. Such robustness is consistent with the reliability requirement of power systems operation, given that the cost associated with constraint violations is very high. Third, for a wide class of problems, the robust optimization models have similar computational complexity as the deterministic counterparts. This computational tractability makes robust optimization a practical approach for many real-world applications. The interested reader can refer to [10] for a comprehensive treatment of the topic.

II LITURERSURVEY

THEORY:-

The faults on 3Ø synchronous generator can be classified as follows;

- 1) L – G Fault, 2) L – L Fault,
- 3) L – L – G Fault, 4) 3 Ø Fault.

From the above no.1, 2 & 3 are the unsymmetrical faults & no. 4 is symmetrical fault. One open conductor disturb the symmetry in one or two phases therefore L – G, L – L, L – L – G are unsymmetrical faults. The current during fault is very high depending on type of fault as compared to normal current therefore the system must be protected against flow of heavy short ckt current which can cause permanent damage to normal & major equipments. By disconnecting faulty part of the system by means of ckt breakers operated by protective relaying are must eliminate the magnitude of current that would flow under short ckt condition this is the scope of fault analysis.

1) Line to Ground (L – G) fault:-

The system to be analyzed as shown in fig. 2. Let the fault takes place on phase ‘a’. The boundary conditions are;
 $V_a = 0, I_b = 0, I_c = 0$. & the sequence network equations are;

$$V_{a0} = -I_{a0} Z_0,$$

$$V_{a1} = E_a - I_{a1} Z_1,$$

$$V_{a2} = -I_{a2} Z_2.$$

We have;

$$\begin{pmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{pmatrix} = \frac{1}{3} \begin{pmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{pmatrix} \begin{pmatrix} I_a \\ I_b \\ I_c \end{pmatrix}$$

Substituting $I_b = I_c = 0$

$$\begin{pmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{pmatrix} = \frac{1}{3} \begin{pmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{pmatrix} \begin{pmatrix} I_a \\ 0 \\ 0 \end{pmatrix}$$

$$I_{a0} = I_{a1} = I_{a2} = I_a / 3$$

Also

$$\begin{pmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{pmatrix} = \begin{pmatrix} -I_{a0} Z_0 \\ E_a - I_{a1} Z_1 \\ -I_{a2} Z_2 \end{pmatrix}$$

We have;

$$V_a = V_{a0} + V_{a1} + V_{a2} = 0$$

Or

$$-I_{a0} Z_0 + E_a - I_{a1} Z_1 - I_{a2} Z_2 = 0$$

$$I_{a1} = \frac{E_a}{Z_1 + Z_2 + Z_3}$$

Since, the sequence currents are all equal in magnitude & phase angle therefore the system 3Ø sequence network must be connected in series. The interconnection of sequence network as shown in fig. ** of 3Ø star connected balance system connected to 3Ø balanced delta load.

2) Line to Line (L – L) Fault:- Let the line to line faults takes place on phases b & c as shown in fig. 3 the boundary conditions are $I_a = 0$, $V_b = V_c$, $I_c = -I_b$ & $I_b + I_c = 0$.

$$\text{By matrix manipulation; } \begin{pmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{pmatrix} = \frac{1}{3} \begin{pmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{pmatrix} \begin{pmatrix} 0 \\ I_b \\ -I_b \end{pmatrix}$$

$$I_{a0} = 0, I_{a1} = (\alpha - \alpha^2)I_b, I_{a2} = (\alpha^2 - \alpha)I_b, I_{a1} = -I_{a2}.$$

$$\text{Also } \begin{pmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{pmatrix} = \frac{1}{3} \begin{pmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{pmatrix} \begin{pmatrix} V_a \\ V_b \\ V_c \end{pmatrix} \quad \text{The sequence network equations are;}$$

$$\begin{pmatrix} 0 \\ V_{a1} \\ V_{a2} \end{pmatrix} = \begin{pmatrix} 0 \\ E_a \\ 0 \end{pmatrix} - \begin{pmatrix} Z_0 & 0 & 0 \\ 0 & Z_1 & 0 \\ 0 & 0 & Z_2 \end{pmatrix} \begin{pmatrix} 0 \\ I_{a1} \\ I_{a2} \end{pmatrix}$$

$$V_{a1} = E_a - I_{a1}Z_1 = I_{a1}Z_2$$

$$I_{a1} = \frac{E_a}{Z_1 + Z_2}$$

Thus, to stimulate L – L fault condition zero sequence network is not required & hence zero sequence current is absent & the negative sequence network are to be connected in opposition as $I_{a1} = -I_{a2}$ & $V_{a1} = V_{a2}$ The interconnection of sequence network for stimulation L – L fault as shown in fig.

3) Line to Line to Ground (L–L–G) fault:-

$$I_a = 0$$

$$\text{i.e. } I_{a0} + I_{a1} + I_{a2} = 0,$$

$$V_b = V_c = 2(I_b + I_c) = 3Z I_{a0}. \text{The symmetrical of voltage are}$$

$$\text{given by } \begin{pmatrix} V_{a1} \\ V_{a2} \\ V_{a0} \end{pmatrix} = \frac{1}{3} \begin{pmatrix} 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \\ 1 & 1 & 1 \end{pmatrix} \begin{pmatrix} V_a \\ V_b \\ V_c \end{pmatrix}$$

$$\text{From which follows that, } V_{a1} = V_{a2} = \frac{1}{3} [V_a + (\alpha + \alpha^2)V_b]$$

$$V_{a0} = \frac{1}{3} (V_a + 2V_b)$$

$$V_{a0} = V_{a1} = \frac{1}{3} (2 - \alpha - \alpha^2) V_b = 3ZI_{a0}$$

$$V_{a0} = V_{a1} + 3ZI_{a0}$$

$$I_{a1} = \frac{E_a}{Z_1 + Z_2 + (Z_0 + 3Z)} = \frac{E_a}{\left[\frac{(Z_1 + Z_2)(Z_0 + 3Z)}{Z_1 + Z_2 + (Z_0 + 3Z)} \right]}$$

$$E_a - Z_1 I_{a1} = Z_2 (I_{a1} + I_{a0})$$

$$I_{a0} = \frac{E_a}{Z_2} - \left(\frac{Z_1 + Z_2}{Z_2} \right) I_{a1}$$

Substituting this value of I_{a0}

II. SYSTEM DEVELOPMENT

Mathematical Model for Economic Dispatch of Thermal Units Without Transmission Loss

Statement of Economic Dispatch Problem:

In a power system, with negligible transmission loss and with N number of spinning thermal generating units the total system load PD at a particular interval can be met by different sets of generation schedules

$$\{PG_1^{(k)}, PG_2^{(k)}, \dots, PG_N^{(k)}\}; \quad k = 1, 2, \dots, NS$$

Out of these NS set of generation schedules, the system operator has to choose the set of schedules, which minimize the system operating cost, which is essentially the sum of the production cost of all the generating units. This economic dispatch problem is mathematically stated as an optimization problem.

Given : The number of available generating units N, their production cost functions, their operating limits and the system load PD,

To determine : The set of generation schedules PG_i ; $i = 1, 2, \dots, N$ ——— (1)

Which minimize the total production cost,

$$\text{Min ; } F_T = \sum_{i=1}^N F_i(PG_i) \quad (2) \quad \text{—————}$$

and satisfies the power balance constraint

$$\phi = \sum_{i=1}^N PG_i - PD = 0 \quad \text{—————} \quad (3)$$

and the operating limits

$$PG_{i,\min} \leq PG_i \leq PG_{i,\max} \quad (4) \quad \text{—————}$$

The units production cost function is usually approximated by quadratic function

$$F_i(PG_i) = a_i PG_i^2 + b_i PG_i + c_i ; \quad \text{—————}$$

$$i = 1, 2, \dots, N \quad (5)$$

where a_i , b_i and c_i are constants

Necessary conditions for the existence of solution to ED problem:

The ED problem given by the equations (1) to (4). By omitting the inequality constraints (4) tentatively, the reduce ED problem (1),(2) and (3) may be restated as an unconstrained optimization problem by augmenting the objective function (1) with the constraint ϕ multiplied by LaGrange multiplier, λ to obtained the LaGrange function, L as

$$\text{Min : } L(PG_1, \dots, PG_N, \lambda) = \sum F_i(PG_i) - \lambda [\sum PG_i - PD] \quad (6)$$

The necessary conditions for the existence of solution to (6) are given by

$$\frac{\partial L}{\partial PG_i} = 0 = dF_i(PG_i) / dPG_i - \lambda ; \quad i = 1, 2, \dots, N \quad (7)$$

$$\frac{\partial L}{\partial \lambda} = 0 = \sum_{i=1}^N PG_i - PD \quad (8)$$

The solution to ED problem can be obtained by solving simultaneously the necessary conditions (7) and (8) which state that the economic generation schedules not only satisfy the system power balance equation (8) but also demand that the incremental cost rates of all the units be equal be equal to λ which can be interpreted as “incremental cost of received power”. When the inequality constraints (4) are included in the ED problem the necessary condition (7) gets modified as

$$dF_i(PG_i) / dPG_i = \lambda \quad \text{for}$$

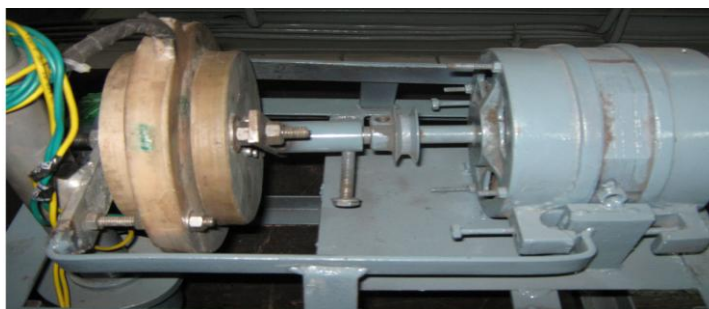
$$PG_{i,\min} \leq PG_i \leq PG_{i,\max}$$

$$\begin{aligned} &\leq \lambda \quad \text{for} \quad PG_i = PG_{i,\max} \\ &\geq \lambda \quad \text{for} \quad PG_i = PG_{i,\min} \end{aligned} \quad (9)$$

$$PG_i = (\lambda - b_i) / 2a_i ; \quad i=1, 2, \dots, N \quad (10)$$

Incremental fuel cost

$$\lambda = PD + \frac{\sum_{i=1}^N (b_i / 2a_i)}{\sum_{i=1}^N (1 / 2a_i)} \quad (11)$$



Photograph 3.5: I.M. Coupled to DRWG

ALGORITHM

- Step 1: Start the Program.
- Step 2: Get the Input Values of Alpha, Beta and Gamma.
- Step 3: Use the Intermediate Variable as Lambda.
- Step 4: Iterate the Variables up to Feasible Solution.
- Step 5: To find Total Cost and Economic Cost of Generator.
- Step 6: End the Program.

PROCEDURE

1. Enter the command window of the MATLAB.
1. Create a new M – file by selecting File - New – M – File
2. Type and save the program.
3. Execute the program by either pressing Tools – Run.
4. View the results.

EXERCISE

1. The fuel cost functions for three thermal plants in \$/h are given by

$$C_1 = 500 + 5.3 P_1 + 0.004 P_1^2; \quad P_1 \text{ in MW}$$

$$C_2 = 400 + 5.5 P_2 + 0.006 P_2^2; \quad P_2 \text{ in MW}$$

$$C_3 = 200 + 5.8 P_3 + 0.009 P_3^2; \quad P_3 \text{ in MW}$$

The total load, P_D is 800MW. Neglecting line losses and generator limits, find the optimal dispatch and the total cost in \$/h by analytical method. Verify the result using MATLAB program.

PROGRAM:

```

clc;
clear all;
warning off;
a=[.004; .006; .009];
b=[5.3; 5.5; 5.8];
c=[500; 400; 200];
Pd=800;
delp=10;
lambda=input('Enter estimated value of lambda=');
fprintf('\n')
disp(['lambda P1 P2 P3 delta p delta lambda'])
iter=0;
while abs(delp)>=0.001
    iter=iter+1;
    p=(lambda-b)./(2*a);
    delp=Pd-sum(p);
    J=sum(ones(length(a),1)./(2*a));
    dellambda=delp/J;
    disp([lambda,p(1),p(2),p(3),delp,dellambda])
    lambda=lambda+dellambda;
end
lambda
p
totalcost=sum(c+b.*p+a.*p.^2)
    
```

Enter estimated value of lambda= 10

lambda	P1	P2	P3	delta p	delta lambda
10.0000	587.5000	375.0000	233.3333	-395.8333	-1.5000
8.5000	400.0000	250.0000	150.0000	0	0

lambda = 8.5000

p =

400.0000

250.0000

150.0000

Total cost = 6.6825e+003

EXERCISE:

2. The fuel cost functions for three thermal plants in \$/h are given by

$$C_1 = 500 + 5.3 P_1 + 0.004 P_1^2; \quad P_1 \text{ in MW}$$

$$C_2 = 400 + 5.5 P_2 + 0.006 P_2^2; \quad P_2 \text{ in MW}$$

$$C_3 = 200 + 5.8 P_3 + 0.009 P_3^2; \quad P_3 \text{ in MW}$$

The total load, P_D is 975MW. Generation limits $200 \leq P_1 \leq 450$ MW

$$150 \leq P_2 \leq 350 \text{ MW}$$

$$100 \leq P_3 \leq 225 \text{ MW}$$

Find the optimal dispatch and the total cost in \$/h by analytical method. Verify the result using MATLAB program.

PROGRAM

```
clear
clc
n=3;
demand=925;
a=[.0056 .0045 .0079];
b=[4.5 5.2 5.8];
c=[640 580 820];
Pmin=[200 250 125];
Pmax=[350 450 225];
x=0; y=0;
for i=1:n
    x=x+(b(i)/(2*a(i)));
    y=y+(1/(2*a(i)));
    lambda=(demand+x)/y
    Pgtotal=0;
    for i=1:n
        Pg(i)=(lambda-b(i))/(2*a(i));
        Pgtotal=sum(Pg);
    end
    Pg
    for i=1:n
        if(Pmin(i)<=Pg(i)&&Pg(i)<=Pmax(i));
            Pg(i);
        else
            if(Pg(i)<=Pmin(i))
                Pg(i)=Pmin(i);
            else
                Pg(i)=Pmax(i);
            end
        end
    end
    Pgtotal=sum(Pg);
    end
    Pg
    if Pgtotal~=demand
        demandnew=demand-Pg(1)
```

```

x1=0;
y1=0;
for i=2:n
x1=x1+(b(i)/(2*a(i)));
y1=y1+(1/(2*a(i)));
end
lambdanew=(demandnew+x1)/y1
for i=2:n
Pg(i)=(lambdanew-b(i))/(2*a(i));
end
end
end
Pg

```

OUTPUT

```

lambda =8.6149

Pg =367.4040 379.4361 178.1598

Pg = 350.0000 379.4361 178.159

demandnew = 575
lambdanew = 8.7147
Pg = 350.0000 390.5242 184.4758

```

RESULT

Economic load dispatch for the given problem was solved using classical method with and without line losses and verified using MATLAB software.

IV CONCLUSIONS

The study becomes a benchmark for reduction of loss occurred in wind turbine system and makes more power efficient which is the need of time.

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