# Contingency Evaluation of Electric Power System at South of Saudi Arabia

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**Abstract - Contingency analysis is a very important analysis for any power system effort. Industry planners and operators must analyze power systems covering scenarios such as the long-term effects on the transmission system of both new generation facilities and projected growth in the load. Contingency criteria refer in this work to the N-2 constraints, which hold that a system must operate in a stable and secure manner following any double transmission line of power links or local generation outage in the Southern power system in Saudi Arabia (SEC-SOA). Analysis shows some power links between different regions of power system could not compensate the outage of local generation to keep the stability and security of the interconnected network. Preventive and corrective actions should be taken under consideration before contingencies referred to power links and local generations in the southern network or between the southern (SEC-SOA) and the western (SEC-WOA)power systems.**

**Keywords:** Power System, Simulation, Load Flow, Contingency Analysis.

## 1. INTRODUCTION

The Kingdom of Saudi Arabia is divided into five geographical regions: Eastern, Central, Western, Southern, and Northern. For all of these regions, there is an interconnected grid that feeds the major load centers of the region. The SEC-SOA power system consists of eight major power stations located in capital cities of the southern regions of the Saudi kingdom [1]. These power stations are mainly connected through 132 kV transmission lines. The existing generation system; as detailed in [2]; has a generating capacity of 2,179MW supplied by 6 major generating stations as illustrated in [2]. Three plants have both gas turbines and diesel generating units, while the other three are powered by gas turbines only. The 132 kV transmission lines are approximate of 150 lines. Data of each line such as resistance, inductive reactance, capacitive reactance and length are available in [2].The power transformers are about 200 transformers connect elements with different voltage levels. There are two power links connect between Western and Southern networks. First a 380 kV transmission line has been erected between Shoiaba and Namera substations. Recently, another transmission line has been erected between Taif and Bisha substations [3] to enforce the connection between SEC-SOA and SEC-WOA power systems.

## 2. MODELS OF POWER SYSTEM ELEMENTS

There are a large number of steady state applications where transmission lines need to be modeled correctly and for only one particular frequency [4-6]. The PW simulator [7] has the π equivalent circuit of a single-phase transmission line that shown in Fig. 1.

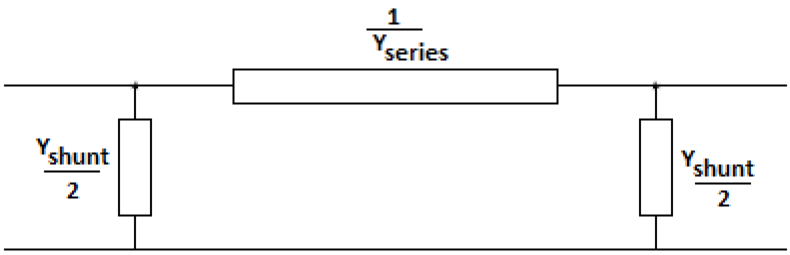


Fig.1 T.L. π equivalent circuit

The series impedance and shunt admittance of the distributed π equivalent circuit of a single-phase line are given in Equations (1) and (2).

$$\frac{1}{Y_{series}} = \frac{(r+j\omega L)l\sinh(\gamma l)}{\gamma l} \quad (1)$$

$$\frac{Y_{shunt}}{2} = \frac{\left(\frac{j\omega C}{2}\right)l\tanh(\gamma\frac{l}{2})}{(\gamma l/2)} \quad (2)$$

where,

r, L, and C are the resistance, inductance, and capacitance per unit length,

l is the line length, and

γ is the propagation constant which is equals to:

$$\gamma = \sqrt{(r + j\omega L)\, j\omega C} \quad (3)$$

Two source models are the most commonly used in power system analysis:

Model 1: Ideal sinusoidal sources behind sub-transient reactances. This model is used for representing large generating stations. The assumption is that the system inertia is infinite and the disturbance under study does not cause system frequency to change and the machine controls such as excitation system and governor have not responded to the disturbance. The main advantage of this model is that the computation requirements are significantly reduced.

Model 2: The detailed model is mostly used for representing small generating stations in nonintegrated systems for applications where the system disturbance is likely to cause change in frequency. The model requires complete machine data including inertia, sub-transient, transient and steady-state reactances. The detail model represents complete machine behavior from sub-transient to steady-state time frames.

The transformer is one of the most familiar and well-known pieces of power system electrical apparatus. Models of varying complexity can be implemented in PW for power transformers. However, ideal transformer model ignores all leakage by assuming that all the flux is confined in the magnetic core. In addition it neglects magnetization currents by assuming no reluctance in the magnetic material. The equations that describe a single-core two winding ideal transformer are :

$$\frac{v_1}{v_2} = \frac{N_1}{N_2} = a \quad (4)$$

$$\frac{i_1}{i_2} = \frac{1}{a} \quad (5)$$

$$\frac{z_1}{z_2} = a^2 \quad (6)$$

where,

$N_1$ and $N_2$ are the turns of windings 1 and 2 respectively,

a is Transformer ratio

$v_1$ and $v_2$ are the voltage of windings 1 and 2 respectively,

$i_1$ and $i_2$ are the voltage of windings 1 and 2 respectively, and

$z_1$ and $z_2$ are the impedance of windings 1 and 2 respectively.

## 3. METHODOLOGY

Contingency evaluation can be developed [4] as follow:

***Step1:*** Southern power network is simulated by Power World Simulator as explained in [2].

***Step2:***The considered initial condition is obtained by load flow analysis. Summary of initial condition is shown in Tables 1 and 2 below:

Table 1 Summary of Initial Condition

| No. | Type | MW | MVAr |
|---|---|---|---|
| 1 | Total Load | 3374 | 1550 |
| 2 | Total Generation | 3474 | 670 |
| 3 | loss | 90 | - |
| 4 | Spinning Reserve | 3990 | - |

Table 2 Initial of Generated Power

| Number of Bus | Name of Bus | Gen MW | Gen Mvar | Set Volt | Max MW |
|---|---|---|---|---|---|
| 275 | TIHCPS | 650 | 110.03 | 1 | 722 |
| 278 | BISHCPS | 310 | 97.42 | 1 | 349 |
| 298 | ASRCPS | 450 | 199.03 | 1 | 726 |
| 331 | NAMNTH380 | 0 | -203.38 | 1 | 1000 |
| 334 | SHOIABA | 263.49 | -205.4 | 1 | 1000 |
| 335 | SQWEC | 0 | 53.87 | 1.03 | 1000 |
| 349 | NJC1 | 200 | 138.8 | 1.03 | 257 |
| 350 | NJC2 | 100 | 64.21 | 1.03 | 112 |
| 375 | JCP_ | 1200 | 621.23 | 1 | 1278 |
| 379 | TAIF | 300 | -205.32 | 1 | 1000 |

***Step3*:**Switch on or off the power link by the circuit breakers.

***Step 4***: Predict the new steady-state of the network variables.

***Step5:***Find out limit violations of the new steady state variables.

## 4. RESULTS OF CONTINGENCY EVALUATION

There are six power links at 132kV level that connect between different regions of the southern network as shown in Fig.2:

1) Dharan Alganoob/Al Khaneq link that connects between Asser and Najran regions.
2) Al Habeel/Addarb link that connects between Jazan and Tehama regions.
3) Bisha/Aqiq link that connects between Bisha and Al Baha regions.
4) Alalaya/Buljurashi link that connects between Asser and Al Baha regions.
5) Two links connect between Tehama and Al Baha regions that are Namera/Buljurashi and Namera/Al Baha East links.

Also there are two links at 380 kV level. The first link connects between Shoiaba power station at the Western Region and Namera substation at the Southern Region. The second link connects between a substation at Taif at the Western Region and Bisha substation at the Southern Region.

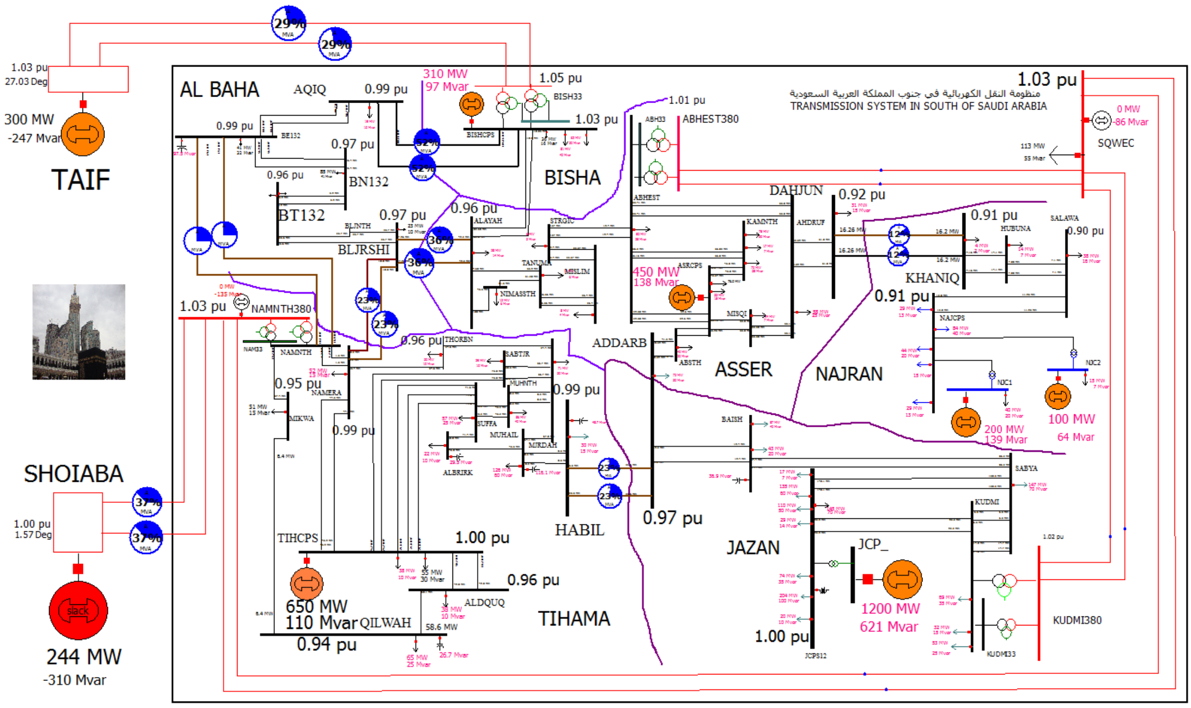


Fig.2 PW single line diagram of Southern power system

## 3.1 CONTINGENCIES OF NAJRAN NETWORK

### 3.1.1 Outage of Asser/ Najran Power link

Voltage violations occur due to the outage of the power link in different locations at Najran area as shown in Table 3. The voltage drop may cause a disturbance in Najran area, and corrective actions are required to prevent a voltage collapse.

Table 3. Voltage violations due to Outage of Asser/ Najran Power link

| Substation | Value, pu | Limit, pu | Nom. kV |
|---|---|---|---|
| KHANIQ (322) | 0.85 | 0.9 | 132 |
| HUBUNA (323) | 0.86 | 0.9 | 132 |
| SALAWA (324) | 0.86 | 0.9 | 132 |
| NAJCPS (325) | 0.89 | 0.9 | 132 |

### 3.1.2 OUTAGE OF LOCAL GENERATION

The power link does not achieve stability and safety of the electrical grid in Najran network due to exit of the local power stations in Najran. Therefore, it is necessary to shed electrical loads at Najran network to mitigate effect of the outage of power plants from service for any reason.

## 3.2 CONTINGENCIES OF JAZAN NETWORK

### 3.2.1 Outage of Jazan/ Tehama Power link

If Power link between Jazan and Tehama is disconnected from the service, the Jazan Network will remain secure and stable and there will be no deviations from the acceptable limits of voltages and currents in the network.

### 3.2.2 Outage of Local Generation

In this contingency, the generating capacity of the generation plant in Jazan 1200 MW. The 400 kV power links between Shoiaba and Namera at Tehama as well as between Namera and Kudmi in Jazan can withstand 60% of the generation capacity. However, if more than 60% exceeded, the 400 kV power links will be shut down from service due to high loads and exceed the acceptable power flow rate on the power lines as shown in the Table 4 below.

Table 4. Power flow violation due to Outage of 80% of local generation at Jazan

| Line | MW Flow | Limit, MW | % |
|---|---|---|---|
| SHOIABA ( 334) -> NAMNTH380 ( 331) CKT 1 at SHOIABA | 643.01 | 533 | 120.64 |
| SHOIABA ( 334) -> NAMNTH380 ( 331) CKT 2 at SHOIABA | 643.01 | 533 | 120.64 |
| NAMNTH380 ( 331) -> SQWEC ( 335) CKT 2 at NAMNTH380 | 558.26 | 533 | 104.74 |
| NAMNTH380 ( 331) -> SQWEC ( 335) CKT 3 at NAMNTH380 | 558.26 | 533 | 104.74 |

## 3.3 CONTINGENCIESOF ASSER NETWORK

### 3.3.1 Outage of Jazan/ Tehama Power link

In the case of disconnection of the Power link between Jazan and Tehama, the Asser Network will remain secure and stable and there will be no deviations from the acceptable limits of voltages and currents in the network. The power flow on 132 kV Aqiq/BE circuits will exceed its nominal values by 5 % as shown in Table 5.

Table 5. Power flow violation due to Outage of Jazan/ Tehama Power link

| **Line** | **MW Flow** | **Limit, MW** | **%** |
|---|---|---|---|
| Element | Value | Limit | Percent |
| AQIQ ( 268) -> BE132 ( 2) CKT 1 at AQIQ | 123.64 | 118 | 104.78 |
| AQIQ ( 268) -> BE132 ( 2) CKT 2 at AQIQ | 123.64 | 118 | 104.78 |

### 3.3.2 Outage of Local Generation

Generation capacity of the power plants in Asser network is 450 MW. For this contingency, The 400 kV power links will be stable. However, the drop voltage level will be within an acceptable margin at different points in the network as shown in the Table 6 below.

Table 6. Voltage violations due to Outage of local generation at Asser

| Substation | Value, pu | Limit, pu | Nom. kV |
|---|---|---|---|
| TANUMA (292) | 0.89 | 0.9 | 132 |
| MISLIM (293) | 0.88 | 0.9 | 132 |
| STRGIC (294) | 0.9 | 0.9 | 132 |
| ABSTH (297) | 0.9 | 0.9 | 132 |
| ASRCPS (298) | 0.9 | 0.9 | 132 |
| MISQI (301) | 0.89 | 0.9 | 132 |
| KAMNTH (302) | 0.9 | 0.9 | 132 |
| AHDRUF (320) | 0.89 | 0.9 | 132 |
| DAHJUN (321) | 0.86 | 0.9 | 132 |
| KHANIQ (322) | 0.86 | 0.9 | 132 |
| HUBUNA (323) | 0.86 | 0.9 | 132 |
| SALAWA (324) | 0.86 | 0.9 | 132 |
| NAJCPS (325) | 0.89 | 0.9 | 132 |

### 3.4. Contingencies of Power Links of Western and Southern Power Systems

In the case of opening the power links between Taif and Bisha, system will remain stable because the power link between Shoiaba and Namera will reinforce the required generation. But when power link between Shoiaba and Namera open, system will be black out if no preventive actions are considered.

## 5. RESULTS DISCUSSION AND CONCLUSIONS

Generally, results of analysis appear that SEC- SO system will be stable if some preventive actions considered before contingencies as shown in next section. Analysis of output data indicates that:

1) The outage of power link between Shoiaba and Namera substations may cause a big disturbance and black out the entire system because the overflow caused on it's both circuits.
2) Loss of power due to the outage of power link between Taif and Bisha substations can be recovered from the local generation in 132 kV system at light load or from Shoiaba / Namera power link at peak load. The related 132 kV transmission lines will be stable because the over power flow through them are in acceptable margin.
3) The outage of 132kV power links create states violations that can be avoided by certain corrective actions. These corrective actions should be given to the system operator before executing the outage of power links.
4) The outage of any power station in the SEC-SO system can be compensated from the SEC-WO system through increasing the power flow of links between the two regions except power plants at Najran area. Voltage collapse can be occurred at Najran network due to the outage of power plants.

## 6. REQUIRED PREVENTIVE ACTIONS

1) Loads at Tehama network should be shed before disconnecting power link between Shoiaba and Namera at peak demand as shown in Fig.3. The disconnected load should be equal to power flow of the power link that will be lost.

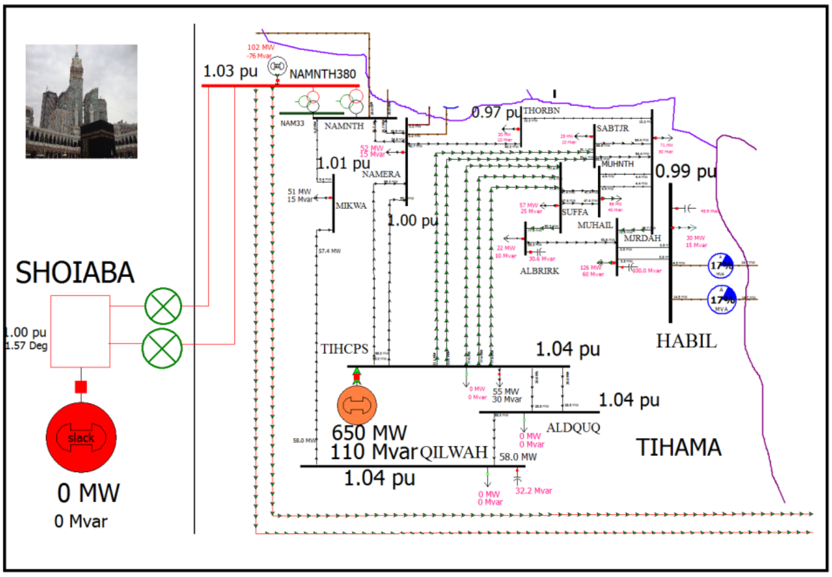


Fig. 3 Tehama network

2) The outage of power link between Asser and Najran regions will not need to any preventive action because loads that were supplied from the power link will be supplied from local power plants as shown in Fi.4. But in the case of generation outage, the power link cannot compensate the voltage drop that will happen. Therefore, some of the local load at Najran region should be shed before reduction any amount of local generation.

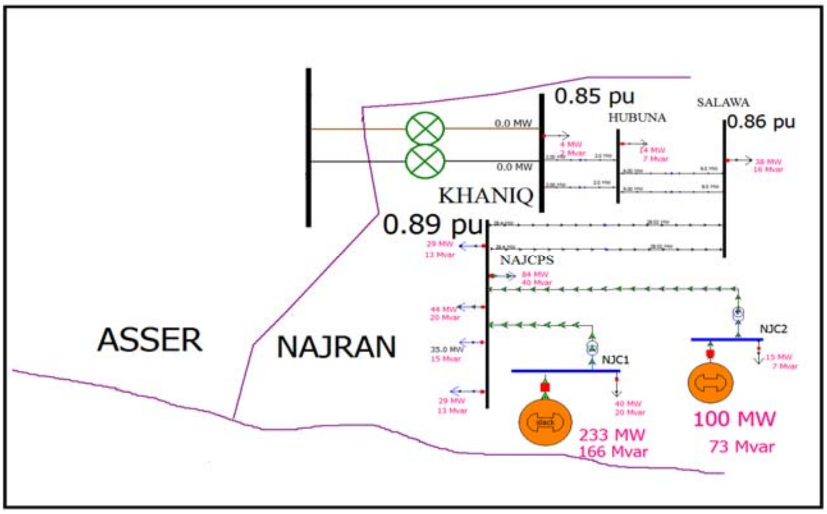


Fig. 4 Najran network

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Gamal A.W. Hazza is born in 1959. He holds BSc in electrical engineering from Aleppo University, Syria, in 1982, MSc in electric power systems from Cairo University, Egypt, in 1991 and PhD in electrical engineering and electronics, from UMIST /Manchester, Britain, in 1999. He has promoted Associate Professor degree in 2004 from the University of Sana'a, Yemen. He was a participant in the training courses in the field of accreditation and quality assurance in 2008 at the Centre for Higher Education Policy Studies (cheps), University of Twente, Enschede, the Netherlands. Currently he is working in Saudi Arabia with Albaha University, College of Engineering, in the Department of Electrical Engineering.