ENVIRONMENTAL IMPACT ON MAIN INTERCONNECTED TRANSMISSION SYSTEM OF OMAN

Thani M S Al-Khusaibi **Masaud Awlad Thani** **Younis Al-Rawahi** **Dr. A K De Bhowmick**

Oman Electricity Transmission Company, Sultanate Of Oman

Abstract

The most significant challenge for the transmission system is to achieve an economical design while meeting many diverse performance requirements and constraints. Primary interest is ensuring that the transmission line is capable of reliably transferring the necessary power at a reasonable cost. Designing a transmission line with minimum environmental impact requires detailed study of various factors. The insulation of the line, airgap, and insulator strings must be designed to withstand switching surges, fault initiated overvoltages, impulses caused by lightning and the reduction of electrical strength caused by contamination of the insulators. Relative air density, humidity, occurrence of rain and fog, and the influence of wind on conductor-to-tower clearances all affect insulation strength. In this paper we will concentrate on the impact of environment on the performance of main interconnected transmission system of Oman.

Key Words: Environment, Humidity, Contamination

1.0 Introduction

The principal function on an EHV transmission system is to transfer electrical energy in bulk from generating plants at various locations to the load centres. So, it is very important to understand both the significance of the transmission system in the overall power system and the impact of the line performance on the reliability of the entire grid. Performance of the transmission network in Oman, due to unpredictable weather condition in some parts of the year is of significant concern. In Oman, the main interconnected transmission system is being operated and maintained by Oman Electricity Transmission Company SAOC(OETC).

Oman Electricity Transmission Company SAOC (OETC) is incorporated as a closed joint stock company (SAOC) in accordance with the Commercial Companies Law No. 4/74 having its registered office in Muscat. The company was formed as part of the privatization of electricity and related water sector activities in the Sultanate of Oman. The company came into existence as a commercial entity following the promulgation of Sultani Decree No. 78/2004, the Law for the Regulation and Privatization of the Electricity and Related Water Sector, generally known in the electricity sector as the 'Sector Law'. The law provided for the unbundling of the electricity and water activities previously undertaken by the Ministry of Housing, Electricity and Water (MHEW).

The company started its commercial operation effective from May 01, 2005 after the Transmission and Dispatch Licence (the Licence which came into force on May 01, 2005) was granted to the company by the Authority for Electricity Regulation (AER) in Sultanate of Oman.

2.0 The Main Interconnected Transmission System

OETC operates the Main Interconnected Transmission System at 220kv and 132 kv in the Northern Region of Oman. This grid interconnects the areas of Muscat Governorate and the regions of Dakhliyah, Batinah, Dhahirah, and Sharquiya. The Grid consists of about 570 kms of 220 kv circuits, 2653 kms of 132 kv circuits & 37 Grid stations.

3.0 Oman Power Scenario:

3.1 Operational Performance

The actual summer peak demand of OETC's main interconnected transmission system in the year 2006 was 2638 MW on 16.07.2006(Centrally Dispatched).

3.2 Load in Distribution areas

At peak the load in the distribution areas are as follows:

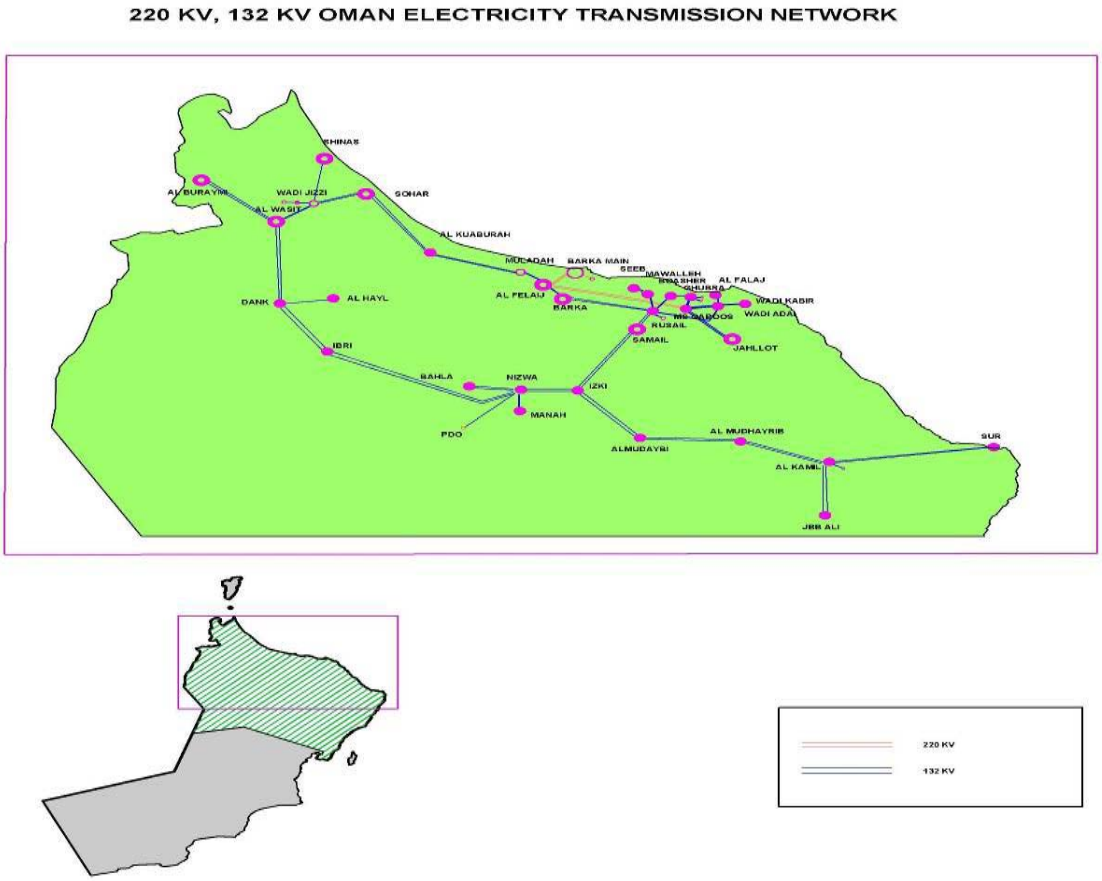
Muscat Disco load 1146.4 MW (46% approx.)

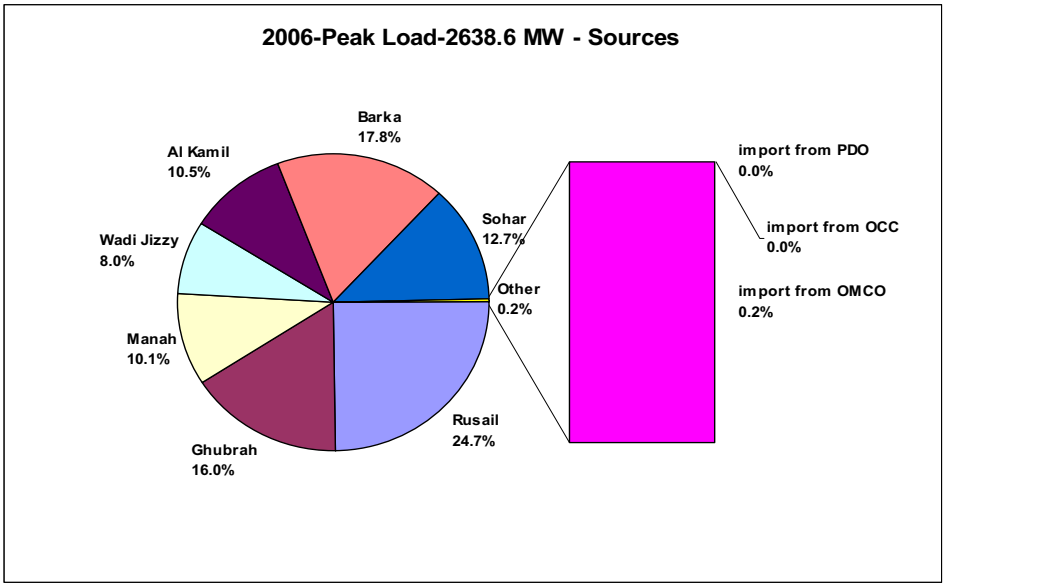
Mazoon Disco load 831.7 MW (33% approx.)

Dakhliyah	238.8 MW
Sharquiya	259.0 MW
South Batinah	333.9 MW

Majan Disco load 527.2 MW (21% approx.)

North Batinah	322.8 MW
Dhahirah	204.4 MW


220 KV, 132 KV OMAN ELECTRICITY TRANSMISSION NETWORK
SOHAR
AL WASIT
AL KUABURAH
BARKA MAIN
AL FALAJ
WADI KABIR
WADI ADAI
AL HAYL
DANK
AL FELAJ
BARKA
RUSAIL
SAMAIL
JAHLLOT
IBRI
BAHLA
NIZWA
IZKI
MANAH
PDO
AL MUDHAYRIB
SUR
AL KAMIL
JIBB ALI
220 KV
132 KV


2006-Peak Load-2638.6 MW - Sources
Barka
17.8%
Al Kamil
10.5%
Wadi Jizzy
8.0%
Manah
10.1%
Ghubrah
16.0%
Rusail
24.7%
Other
0.2%
Sohar
12.7%
import from PDO
0.0%
import from OCC
0.0%
import from OMCO
0.2%

Summary of Regionwise System Incidences

Months 2005	Muscat	Sharquiyah	Dakhliya	Dhahirah	South/North Batinah	Total	Significant Incidents
January	2	9	1	0	0	12	0
February	1	4	0	2	2	9	5
March	6	1	0	5	1	13	3
April	3	2	0	5	3	13	9
May	1	1	0	9	1	12	3
June	0	2	0	0	1	3	3
July	0	1	0	0	11	12	5
August	1	1	1	3	8	14	**13**
September	4	5	0	1	4	14	6
October	4	4	3	1	3	15	2
November	1	7	1	0	9	18	2
December	2	3	0	0	6	11	0
Total	25	40	6	26	**49**	**146**	**51**

4.0 **Weather dependent multiple faults & trippings affecting wide area of the network**

The salt of the sea, sand of the desert, and air pollution which every developed society produces, all settle on the exposed high voltage insulators producing leakage currents with the risk of flashover and consequent loss of supply.

In 2005, OETC grid faced 146 nos. of line trippings/ partial disturbances. The summary of the grid incidences are given in the above table.

From the above it may be seen that, among the areas of Muscat, Sharquiyah, Dakhliyah, Dahirah and South/North Batinah, the maximum number of failures (49) have taken place in South/North Batinah. Whereas, Dakhliyah area had faced minimum number of failures (6).

After South/North Batinah areas, next critical area is Sharquiyah region, which had faced 40 numbers of disturbances in the year.

It may be mentioned that all the failures are not of same severity. Hence "Significant Incidents" have been identified separately. In the above, 146 number of incidences, 51 incidences are of critical nature, so they have been designated as"Significant Incidents". It may be seen that the number of significant incidences are maximum in the months of August/September, when environmental humidity is also maximum. Hence a correlation may easily be established between 'Humidity' and critical 'System Occurrences'. Where as, in November, December & January (low humidity period) even though number of incidences are 18, 11 & 12 respectively, the system criticality and significant incidences are negligible.

In the above incidences, 36 (24.65%) numbers of incidences took place under inclement weather condition, viz. rain, lightning, thunder stroke, sand storm, heavy wind e.t.c. 40 (27.39%) number of incidences had taken place under high humidity and foggy weather conditions. Hence in the total number of incidences more than 52% had taken place under adverse weather situations.

In the context of the above, it may be mentioned that weather plays a very significant role in the operation of the main interconnected transmission system in Oman.

4.1 **The Analysis**

A nationwide analysis by OETC, on the contamination performance of power transmission system in Oman revealed many different aspects of insulator contamination and supplied valuable information.

In the Muscat area, the transmission system crosses mostly through the mountain range, so environmental pollution is appreciably less. Whereas, in South/North Batinah areas, a lot of non-metalled roads crosses under the transmission system so any vehicular movements generates significant dust pollution. In Dakhliyah area, trippings are quite less as the sources of contamination as well as humidity levels are low. In Dahirah area trippings usually takes place due to rain, lightning & heavy wind. High humidity prone zones are mostly Muscat, Sharquiyah & South/North Batinah areas.Transmission system trippings are generally quite high near to the coastal areas as well as industrial areas (where cement factories etc. are located).

5.0 The Reason

Contamination flashovers on transmission systems are initiated by airborne particles deposited on the insulators. These particles may be of natural origin or they may be generated by pollution that is mostly a result of industrial, agricultural or construction activities. A common natural deposit is sea salt, which causes a severe contamination of transmission line insulators in coastal areas and even in inland areas. In industrial or agricultural areas, a great variety of contaminants may reduce insulation strength. These deposits do not decrease the insulation strength when the insulators are dry. The loss of strength is caused only by the combination of two factors: Contaminants and Moisture. In fact, moisture is always necessary to produce a conductive layer on contaminated insulator surfaces.

Insulator contamination poses a serious threat to reliable transmission-line operation because a contamination flashover is frequently followed by a second flashover of the same insulation within a short time.

6.0 Factors that affect wetting mechanism

It is commonly recognized that flashovers caused by dust and moisture may occur during very humid weather, such as drizzle, fog or simply high humidity conditions. Contaminated insulator surfaces may be as dry as clean ones in fair weather. Consequently, these flashovers occur as a result of the transition from dry to humid weather.

Generally, it is difficult to recognize,from the moistened to the entirely wetted state because the change occurs very gradually. In addition, it should be noted that the wetting process on contaminated insulator surfaces is different from the dew formation on clean surfaces. Many factors influence weather wetting conditions are severe enough to cause flashovers.

7.0 Effect of Humidity

Flashover voltages for airgaps and insulators depend on the absolute moisture content of the air..

The breakdown voltage V, at any vapour pressure is usually described by,

$$V = Vo / H$$

Where Vo is the breakdown voltage at standard conditions (15.2 mmHg vapour pressure) and H is a humidity correction factor that depends on gap geometry.

8.0 Type of Contaminants

Most contaminants, such as salt, cement and fertilizer, are not good conductors in completely dry conditions. These materials require a moderate amount of moisture before their conductivities become appreciable. As a moisture film builds up on a contaminated surface the soluble electrolytes within the contamination coating gradually dissolve. A thin film of conducting liquid then forms on the insulator surface. The conductivity of this film depends on the amount of moisture as well as the chemical composition of the contaminant.

9.0 Type of Moisture

The moisture impinging on a contaminated insulator may vary from a mist or light fog to a heavy rain. Moisture may impinge on the insulator surface gently, as a lightly falling mist would, or it may be wind driven. However, with the exception of coastal areas, fog usually occurs during periods of low wind velocity. Heavy rain may actually be beneficial because it tends to wash off the layer of contaminant quite rapidly.

10.0 Relative Humidity and Leakage Current

As the layer of contaminant becomes wet, it turns into a conductive film with the leakage current increasing correspondingly. The leakage current density is nonuniform, and in some areas sufficient heat is developed to evaporate more moisture than is falling onto the surface. When this situation occurs, the well known process of dry band formation takes place.

The degree to which dry band form initially and the rate at which they reabsorb moisture depends on the relative humidity of the air surrounding the insulator string because the closer the air is to saturation, the more the evaporation process is hindered and the more reabsorption is enhanced. In a situation of falling rain, the wetting action is also a function of the amount of rain actually striking the insulator surface. As a result, dry band formation may not be possible until after the rain ceases

11.0 Process of Natural Wetting conditions

During the day, the insulator surface is dry, and the temperature is above ambient. With the passage of time, there is a gradual, and difficult to recognize, transition from the dry to a moistened and then to an entirely wetted state.

As the wetting condition progresses, the impedance changes from capacitive to resistive. Usually, its value decreases markedly when the humidity reaches 85-90%.

12.0 Types of Contaminants in Oman

The mixed contamination condition is the most common in Oman. This condition was defined as the combination of industrial pollution and sea salt or the combination of several industrial pollutions. Fog, dew, drizzle and mist are common weather conditions accounting for 52% of the total trippings. A combination of dew and fog is regarded as the most severe wetting condition, although fog is not necessary for the wetting process, being only a sign of saturation of

water vapour in the air. In fact, many flashovers occurred as a result of dew only.

13.0 Measures taken by OETC

a) **Washing**
Washing and cleaning of insulators are being done regularly. Live-line washing are also being done as and when required. Based on the experience gained by OETC regarding area-wise pollution level and weather dependent transmission line tripping scenario, a completely new procedure has been formulated and adopted by OETC regarding cleaning cycle of insulators.

b) **Silicon Rubber insulators**
Efforts have already been taken by OETC to identify the critical areas prone to contamination and high humidity. Initiative has already been taken by OETC to replace existing insulators with Silicon Rubber Insulators (total 612 nos.) in the following lines:

a) 220KV transmission lines between Barka Power station and Filayj grid station.
b) 220KV transmission lines between Sohar Power station and Sohar Interconnected grid station
c) 132KV transmission lines between Alkamil grid station and BB Ali grid station.
d) 132KV transmission lines between Alkamil grid station and Sur grid station.

14.0 Conclusions

It may be concluded that the insulation of the line, airgap, and insulator strings must be designed to withstand switching surges, fault initiated over voltages, impulses caused by lightning and the reduction of electrical strength caused by contamination of the insulators.

It is well known that relative air density, humidity, occurrence of rain and fog, and the influence of wind on conductor-to-tower clearances all affect insulation strength. Analysis of actual system incidences of Main Interconnected Transmission System of Oman indicates that environment plays a very significant and important role.

In spite of all the adversities, the availability of transmission system in Oman is comparable with world standards. In the year 2005, availability was 97.7% and it is hoped that with all out effort and dedication of OETC, the availability will improve further in 2006.

References:

1) OETC System Condition Report (summer)-2005 & 2006**.**
2) OETC Five Year Annual Transmission Capability Statement