ENERGY RISKS AND ASSET MANAGEMENT PROBLEMS CAUSED BY AN UNEXPECTED WEATHER CONDITIONS IN ELECTRICITY DISTRIBUTION OF IRAN

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ABSTRACT

This paper introduces and analyzes an extraordinary crisis in which an extremely cold weather covered a major area of the Iran during winter of 2007. This caused serious problems for the country's energy sector and electricity distribution in Iran. This crisis, particularly in the energy distribution sector, left uncompensated for two months. Here, this situation is discussed in detail in view of the relevant data and information. It is also presented detailed events in some regional distribution areas. To further examine the issue, risk management weaknesses at that time horizon are discussed and somehow criticized. Finally, some remarks and proposals are proposed which could improve the performance of the energy generation and distribution sector during such a crisis.

INTRODUCTION

During winter of 2007, Iran experienced some of the most extreme winter weather in recent history. An unprecedented cold weather covered a major area of the country (Fig.1) which was unexpected enough to make a serious crisis for the electricity distribution in Iran. This crisis, particularly in the energy distribution sector, left uncompensated for two months. As a result, energy sector of the country faced with several new situations that could impact the reliability of the Iran grid during such extreme cold weather conditions.

Considering the fact that the country owns a considerable portion of the total natural gas resources of the world by approximately 17 percent, the energy generation sector as well as heating applications have a strong dependency on this resource. Such reliance caused a major shortage, when the weather in that winter became as cold as minus 30 degrees centigrade in some regions. This became even worse when the people start to use electricity for heating. It can be seen the sudden temperature changes along with the total consumed gas by power plants and from consumers by comparing average figures of 2007 with the years 2005, and 2006 in Fig.2.

On the other hand, these serious conditions caused serious damages and outages to distribution and generation equipment and several substation units shutdown making the situation more alarming. Another issue was about the steam power units which forced to turn off due to freezing weather. In this environment, the distribution companies faced with serious asset management problems left to remain unsolved. Besides, there are few papers on this subject so far [1-4]. Therefore, an extended discussion could be very helpful.

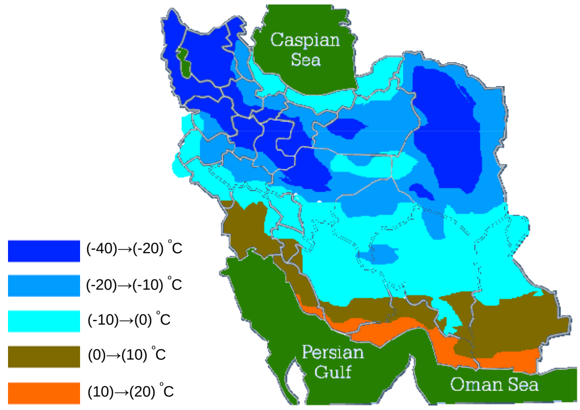

Fig. 1. Average thermal map of Iran for two-weeks during winter of 2007.

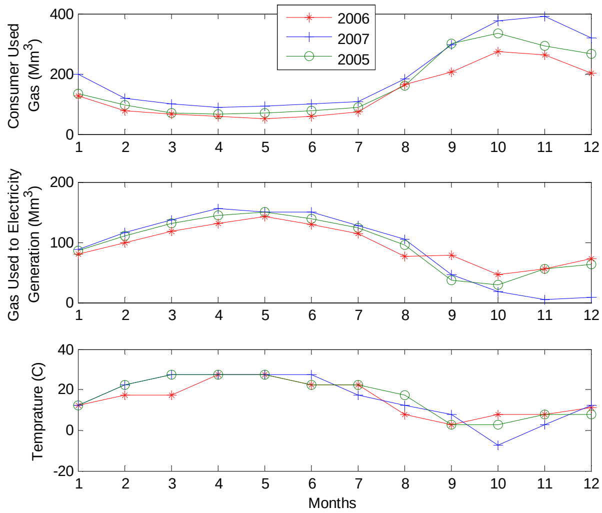

Fig. 2. Comparison of the average temperatures, the total consumed gas by power plants and by consumers for years 2005-2007.

In this paper, the aforementioned situation is discussed in detail considering enormous data and information. It is also presented detailed occurrences in some regional distribution areas. To further examine the issue, this paper primarily addresses the need for electric scheduling certainty necessary to support day-ahead gas nominations by owners of natural gas units. In addition to enhancing the coordination of the gas and electric industry this paper also defines processes that will enable the distribution companies to forecast and operate with greater certainty and facilitate better asset management during cold weather conditions. Meanwhile, the risk management weaknesses at that time horizon are discussed and somehow criticized. The presented discussions cover some asset management problems in the real-time, short-term, and mid-term context. The Final remarks are devoted to some critical proposals which may improve the performance of the energy generation and distribution sector during such a crisis. The proposals are developed from the viewpoints of risk and asset management and aimed at minimizing the risks both the energy sector and the people suffered.

GENERAL VIEWPOINT

As a first view, coping with extreme weather conditions and mitigation of its impacts on distribution assets require either **mitigation** of the weather event or **adaptation** to the weather event. Of course, the former, even if it seems unattainable, requires very long-term climate management programs and is not relevant here. The latter, as the unavoidable situation here, could be able to respond to the predicted impacts of unavoidable weather change.

One could advise two broad approaches (others approaches may exist) to adaptation with extreme weather crisis: **(1) scenarios based approach**, which uses science-based, modelled projections of future weather from which to explore potential impacts and responses, and **(2) vulnerability based approach**, which involves understanding the ability of a system to cope with adverse effects of weather change and adaptive capacity within companies [3].

On the other hand, all customer energy data, whether monthly, daily, or hourly, are correlated with historical weather. Therefore, the weather sensitivity (separately for cooling and heating end uses) as well as the fraction of non-weather sensitive end-uses should be determined. To take into consideration the weather sensitivity of customers the use of a tuning equation is proposed in the context of a distributed asset optimization (DAO) model [2]. This model is proposed to the planning and more optimized asset management of distribution systems.

There are three distinct levels of weather situations that may refer to as a **cold weather event**. One definition may be applied as follows, according to [4]:

- **Cold weather conditions** means any calendar day when that day's effective temperatures are forecast to be equal to or less than -18°C for any single on-peak hour and that day's total effective heating degree days are forecast to be greater than or equal to 18°C.
- **Cold weather watch** means days when cold weather conditions are forecast to exist and the 7-day capacity margin forecast indicates a capacity margin greater than or equal to 1,000 MW.
- **Cold weather warning** means days when cold weather conditions are forecast to exist and the 7-day capacity margin forecast indicates a capacity margin less than 1,000 MW. In addition, a cold weather warning will be used for all future days within the 7-Day capacity margin forecast when a capacity margin of less than or equal to 0 MW exists for days not yet declared as a cold weather event.
- **Cold weather event** means days when cold weather conditions are forecast to exist and the 7-Day capacity margin forecast indicates a capacity margin less than or equal to 0 MW for an operating day. Cold weather events are declared by 1100 hrs two days prior to the operating day. A cold weather warning will be used for all future days within the 7-Day capacity margin forecast when a capacity margin of less than or equal to 0 MW exists, until such time that the ISO declares a **cold weather event**.

The recovery of extraordinary fuel expenses during **cold weather events** necessitates the settlement of several strategies in the market processes. Some practical guidelines could be found in [4], where, market participants must go along with the ISO alleviations such as updating fuel contracts in the mid-term and prior notifications in the short-term and real-time. As a result, such cost recovery mechanisms, along with planning and operating with adequate data, could prevent large capital outlays and over-built distribution systems. Anyhow, distributions systems can expect significant benefits from capability to assess failure risk from extreme weather. In the following text, a real lasting cold weather situation is discussed for a naive system.

THE COLD WEATHER IMPACTS

As could be seen from Fig.1, an extremely cold weather was settled down all over the country starting from January 2007. The arid regions of north-east Iran was suffered more, because, the companies were completely inexperienced facing with such an extreme temperature drop (e.g. the temperature changes in Mashhad city was about -11.4°C and the recordings in Shariati power plant reached -33°C – see Fig.3). These weather events did not have any previous records in the past 44 years.

Fig. 3. A power plant in Khorasan province, north-east Iran during Feb. 2007 [5].

In this section, an overview of the reported events and damages by some of the greatly suffered regional distribution companies during winter of 2007 is presented. The data are from Khorasan and Tehran regional electricity companies.

Impacts on the Generation

As somehow mentioned in the introduction, impacts of the cold weather event along with removing gas from fuel composition of the main generation units boosted the electricity crisis at that time. On the other hand, serious transportation problems of other types of fuels in addition to the impossibility of storing liquid fuels in that conditions and/or using existing equipments, caused several units to shut down. This caused unusual blackouts and excessive generating asset amortization (note that those plants are gas-operating and using them with liquid fuels during start-stop long time intervals caused serious unavoidable damages).

In addition to the aforementioned problems, several equipments suffered from serious damages including utilities and pipes cracks/outages duo to ice and falling icicles, damages particularly on the instrumentation and control equipment, and etc. Without detailed listing of all damages and problems, some of the corrective/preventive actions took at that time and some recommendations are presented as follows.

Generation Actions During Winter of 2007

The process of determining and performing corrective and preventive actions is of a major importance in asset management. Actions taken to eliminate the cause of an undesirable situation are corrective actions including remedial action along with cause analysis. On the other hand, actions taken to eliminate the cause of a potentially undesirable situation are known as preventive actions that include risk assessment and continuous improvement.

Some of the remedial actions that were taken at that time include: providing more liquid fuel by the National Iranian Oil Products Distribution Company (NIOPDC), increasing the number of personnel and liquid fuel nightshifts, improving/constructing liquid fuel-related storage/ management facilities, bypassing some of the automatic instrumentation by hand-operated control (which caused an increased operational risk but fewer power-cuts), providing required insulating material and improving internal heating to prevent freezing, and various other actions that in spite of insignificancy, were very helpful in such an unexpected condition.

As a cause analysis, various factors should be discussed; however, some of the more predominant problems are the fuel, the temperature which the equipments were designed for, personnel training/readiness, and lack of the fitting equipment. For the first case, it should be noticed that a great share of the plants were optimized to use gas but liquid fuel. On one hand, the provided storage capacity for liquid fuel was to generate power for 10-20 days while the existing transportation capacity could be able to provide half of the required fuel infeeds. On the other hand, former contracts with the National Iranian Gas Company (NIGC) are on the contrary to the plants' needs.

The temperature for which the equipments were designed reaches minimum at -24°C while the operational temperatures during winter of 2007 were as low as -37°C in some regions.

Some recommendations for improving performance of generation section, based on the 2007 experiences, may be as follows.

1) Fuel type and usage of the power plants should be coordinated with national oil companies, particularly during winter days.
2) The generation capacity obtained from storing liquid fuel should be increased, as a matter of fact, from 20 days to 60 full-load days. Also, the facilities relevant to utilizing/transporting liquid fuel should be provided.
3) To minimize the negative impacts of using liquid fuel on the gas-operated plants, the quality of such a fuel must strictly conform to standards (e.g. ASTM-D2880). An increased corrosion was reported for plants in the Khorasan province due to non-standard liquid fuel by 1360 percent [5].
4) Providing required equipment and improving the operating margins for more severe cold weather events. This may include, for example, some improved insulation, using suitable low-temp. oils, installing the instrumentation/control equipment indoor, extended heat tracing, and etc.
5) Personnel should be trained for such an event, particularly, for manual operations.

These are somehow preventive actions which may generally refer to as staff training, servicing/developing equipment, monitoring equipment, and validating method-s. Consequently, there is a high degree of confidence that these procedures are effective and correct results are obtained. A risk assessment must be performed when any new procedure is introduced or any change to an existing procedure takes place. It is sufficient to document the new procedure, ensuring that due consideration has been given to all important critical control points and any risks associated with all activities within the process. Typically, for complex new procedures, this may involve producing a flowchart of the procedure, incorporating all key steps, documenting all the possible risks associated with each step, documenting how these risks should be minimised and, lastly, documenting the procedure, taking into account all the critical control points [6]. On the other hand, continuous improvement is a procedure that identifies and addresses improvements in the system and also potential sources of non-conformances.

Impacts on the Distribution Network Operation

According to [5], during the first period of cold weather event in the Khorasan province, the Buchholz relays of 8 transformers at the sub-transmission level mal-functioned (due to the oil shrinkage); outdoor equipment mal-functioned and several sectionalizers did not opened; feeders, lines and transformers are left unrepaired without any proper vehicles for mountainous regions; and increased short circuits of several feeders due to heavy snow falls and conductors galloping reported.

To provide another comparison, we consider the feeder outages data for Tehran outskirts distribution network. The

Table I. Causes of feeder interruptions during Jan. 2-7, 2007 compared to the same interval in 2008 and 2009.

Damavand Area			Varamin Area			Roodehen Area			
2009	2008	2007	2009	2008	2007	2009	2008	2007	Dominant causes of interruptions
0	0	14	2	0	15	1	0	21	Heavy snowfall and hurricane
5	3	3	3	9	4	3	3	4	Transient faults (Tranditional)
0.75	0.11	15.87	1.7	3.19	61.29	1.15	1.81	97.59	Total un-distributed energy (MWh)
64	16	632	58	63	2020	25	23	2920	Total blackout time (Min)

causes of feeder interruptions are presented in Table I in the studied time period (from Jan. 2-7, 2007) in comparison with the same interval for years 2008 and 2009. It is obvious that a great amount of energy could not be distributed due to the cold weather event. Fig. 4 depicts a detailed chart of the events for Roodehen area.

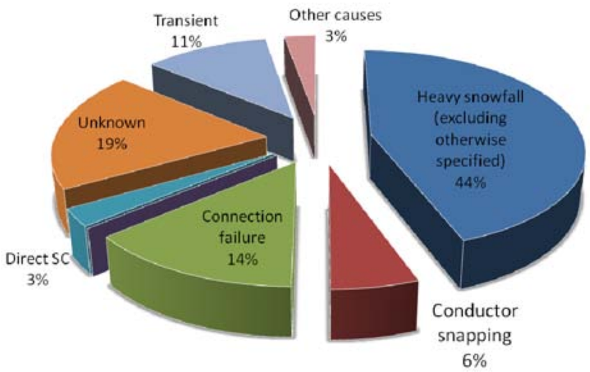

Fig. 4. Feeder interruption details for Roodehen area during Jan. 2-7, 2007

Considering a definition for the asset management as "the process of maximizing the return on investment of equipment by maximizing performance and minimizing cost over the entire life cycle of that equipment", system asset management considering such cold weather events could encompass the maintenance and operation of equipment throughout the weather event too. To answer the asset management questions (e.g. see [7]), the benefits of an increased reliability during cold weather events should be assessed (may be by a corrective/preventive study - see the last paragraph of page 3). In such a way, asset management can offer more comprehensive purchasing decisions, operating schemes, and maintenance scheduling for improving the return on capital investment for the whole year (including a potential cold weather event).
An economic loss analysis is reported in Table II, repeated from [5]. The estimations are for the Khorasan regional electricity company neglecting the price differences for the imported liquid fuel during 4 months. The total loss estimation was reported to be about M$ 8.0129.

CONCLUSION

This paper introduces and analyzes an unexpected cold weather event during winter of 2007 which covered a major area of Iran. Some real information and data are presented to provide an acceptable view on the impacts of such an unprecedented extreme event and its associated problems. Several outcomes are reviewed and some recommendations are proposed as preventive actions. The discussions prove that a proper corrective and preventive set of actions should be strictly followed to go reliably and economically over such a crisis.

Table II. Economic loss estimation during winter of 2007 [5].

Source	Penalty	Loss due to reduced generation	Loss due to non-distributed energy	Equipment loss
Khayam PP				2.0000
Tous PP				1.0000
Mashhad PP				0.5000
Shariati PP				1.0000
Shirvan PP				1.0000
Market & ISO	0.2223	1.4084	0.8804	
Substations, Feeders, etc				0.0018
Sum (Million $)	0.2223	1.4084	0.8804	5.5018

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