Expansion of a Control Center System: Emergency and Backup Setups

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Abstract: - This paper presents the findings of part of a study that involves formulating an optimal development plan for the upgrading, expansion and replacement of the supervisory control and data acquisition, energy management systems (SCADA/EMS) systems and associated telecommunication networks for the efficient operation of the Kuwait Power System. This paper deals specifically with designs that are proposed for the expansion of an electrical control centers system. The objectives of this expansion are to increase operational security and provide a backup for the SCADA systems. Emergency and multi-site setups are proposed to support the operational security and SCADA systems backup, respectively. The criteria for reducing expenditure and enhancing reliability of a particular setup are the systems and sub-systems compatibility and geographical locations.

Key-Words: - District Control Center, EMS, National Control Center, reliability, SCADA, security.

1 Introduction

The electric power system of Kuwait's Ministry of Energy has been developed over the years to provide sustainable and reliable energy supply sufficient for industrial, commercial, and residential needs. To maintain the quality and reliability of the energy supply (both technically and economically), the power system's components, including control centers, must be continuously evaluated, upgraded, and/or replaced.

Worldwide, the configuration of control centers has kept pace with the rapid evolution of computing and information technologies. The advent of computer networking, particularly the Ethernet local area network (LAN) and client-server architectures, has resulted in a complete redesign of the classical control center configuration. Processing, as well as databases, have come to be distributed among different servers and user workstations. Optical fiber has become more widely used as had Ethernet cables. In control center hierarchies, communications among control centers utilizing wide area networks (WANs) and personal computers (PCs) are being integrated in the control center configuration as clients or as remote terminals in engineering or executive offices. Web technology is being applied to make data and graphic display to users with Web browsers. Currently, control center infrastructures are evolving into huge computer networks that may consist of an independent systems operator (ISO) control center linked to a power exchange, a transmission control center hierarchy, intranets and extranets, and other ISOs.

Many studies have either proposed or described such advanced, existing, control centers. Examples of some of the topics studied include: Internet interface to supervisory control and data acquisition (SCADA) systems for inter control center data exchange [1], agent technology in the context of distributed artificial intelligence to support the construction of a new generation of energy management systems (EMSs) in an open environment [2], and expert systems for emergency operation of power system restoration in a control center [3]. A discussion of fundamental design aspects of modern EMS and distributed management systems (DMSs) is reviewed in [4].

Operation of a power system, including power generation, transmission and distribution, is achieved with the implementation of two types of control centers. The first type is for the generation and transmission of the electric power, and the second type is for the distribution of the electric power. These centers may consist of several control centers arranged in a hierarchy. The reliability of the electrical control center system plays a significant role of the well-being of the overall power system [5]. Therefore, investment in control centers has become a priority in electric utilities e.g., [6], [7].

The control center security has a strong influence power system security. Enhancing control center security may be achieved by improving EMS, e.g., [8], [9], and control center communication systems, e.g., [4], [10], and developing backup systems, e.g.,

[11] and intelligent control systems, e.g., [12]. A significant concept in designing reliable, secure control center systems is the emergency control center. The establishment of an emergency control center can improve the redundancy and availability of power system operation.

This paper describes the scheme that was proposed to enhance the reliability of the control centers functionality in Kuwait [13]. The control center system structure in Kuwait is adequate for efficient supervision of the power system. However, a major shortcoming is the absence of a back-up or emergency setup structure. Section 2 provides an overview of the hierarchical structure of Kuwait's control center. Section 3 presents the emergency control center configuration. Section 4 presents the multi-site setup that supports the backup functionality. Section 5 summarizes the work.

2 Present Hierarchical Structure of the Electrical Network Supervision

Real-time control of the electrical network in Kuwait is hierarchically structured and consists of three levels (Fig. 1). Communications between National Control Center (NCC) and District Control Centers (DCCs) are established via the Inter Control Center Communication Protocol (ICCP). The communication channels between the DCCs and the substations' remote terminal units (RTUs) include power line carriers (PLCs), pilot cables, fiber optics and microwave channels. The transmission and sub-transmission system is monitored and controlled as described below.

2.1 Level 1: National Control Center

The entire 275 kV transmission system, power stations and some 132 kV substations are supervised by the NCC. The NCC is responsible for the operation of Kuwait's power system as a whole; specifically it is responsible for the following:

- Long, medium and short term planning of the future operation of the power system.
- Proper functioning and administration of the Power System.
- Control and monitoring of the entire bulk transmission network consisting of all 275 kV and major, interconnecting 132 kV transmission lines and substations.
- Voltage control in the 275 kV, 132 kV network under its supervision and the voltages at the in-feed points to the 132kV, 33 kV and 11 kV networks (bus voltage).
- Security analysis of network under its supervision and applying control actions that achieve the goal of system security and economy.
- Supervision and monitoring of system and frequency and initiating corrective measures as necessary.
- Determination of the spinning reserve for large and medium sized power stations. At any given time, sufficient instantaneous spinning reserve (ISR) should be avaiilable in the system to overcome the loss of generation due to the tripping of two of the largest heavily loaded units in any power station
- Coordination of power plants in the country, with control of the units and the power plant substations being the responsibility of the power plants.
- Co-ordination of generation plant and transmission line equipment maintenance (outage scheduling).
- Restoration of the system after partial or total blackouts.
- Analysis of outages affecting the power system and equipment.
- Preparation of system operation statistics.
- Preparation of management reports together with other reports related to the operation and performance of the power network.

2.2 Level 2: District Control Center

At present in Kuwait, there are four DCCs, which form the second dispatch level under the NCC. Table 1 presents brief descriptions of the existing DCCs.

Table 1. District Control Centers

DCC	Supervised & Controlled Substations	No. RTUs
Jabriya	132/33/11, 132/11, 33/11 kV	122
Shuaiba	132/33/11, 132/11, 33/11 kV	114
Jahra	132/33/11, 132/11, 33/11 kV	82
Town	132/33/11, 132/11, 33/11 kV	59

The transmission and distribution networks starting from 132 kV down to 11 kV, which feed the distribution systems, are supervised by the respective DCCs, which are responsible for the following:

- Control and monitoring of the 132 kV and 33 kV substations forming the points of interconnection points between the transmission network and the distribution system.
- Monitoring and coordination of switching operations within the 132 kV, 33 kV and 11 kV networks within the District under their responsibility.

Jabriya DCC is integrated in the SCADA system of NCC. Separate operator workstations are installed in a separate building near the NCC.

2.3 Level 3: Substation Control Level

In the hierarchical structure, local control at the substations (S/S) can be considered the third level of network control. Since the S/S in Kuwait are not manned under normal circumstances, such station control is only utilized in emergency situations or during station maintenance. Switching actions at the station level are only initiated on request and in coordination with the NCC and DCCs.

Operation of the power plants including the associated S/S is entirely under the control of the power plant management, and any switching concerning the connection of the generating stations with the network are coordinated with the NCC.

3 Proposed NCC Emergency System

To establish an emergency control center for the NCC, it is recommended that one of the DCCs be upgraded rather than building a new control center. The selection of a particular DCC among the available centers for carrying out the functions of the NCC emergency system is based on compatibility of the controlled RTUs and geographical location, with compatibility being given higher priority than location. The Shuaiba DCC's associated RTUs are of the same manufacture as those associated with the NCC. Moreover, the Shuaiba DCC location permits work for infrastructural expansion and upgrading. These advantages would allow the establishment of an emergency NCC at the Shuaiba DCC in a relatively short period of time and should also save on expenditure. An overview of the proposed configuration is depicted in Fig. 2.

The operational features of NCC and NCC Emergency System are as follows:

- In normal operation:
  - The 275/132 kV RTUs associated with the NCC provide information to the NCC and the Shuaiba DCC in parallel.
  - Operation for the substations is managed from the NCC.
  - The control direction of the Shuaiba DCC for these RTUs is blocked.
- In emergency operation:
  - The blocked control direction of Shuaiba DCC is released
  - All SCADA functionality for the 275/132 kV substations are managed via Shuaiba DCC.
  - Operation of the Shuaiba DCC substations is carried out.

The upgrading of the Shuaiba DCC to backup the NCC could be done in two steps (stages), which are discussed in the following subsections.

3.1 Stage1: Realization of Emergency System Functionality for the NCC with Basic SCADA Functionality

This stage constitutes an interim solution. The Shuaiba DCC is extended to work as backup for the NCC with basic SCADA functionality, without EMS and network security functionality. To take over the NCC functionality in case of a total outage of the NCC, the Shuaiba DCC must perform a general interrogation of all RTUs associated with the network supervised by the NCC. In this case, all manual data entries by the dispatchers at the NCC, e.g., hand dressed status indications which would not normally be available at the Shuaiba DCC. The database population and modification of video display units are performed at the NCC and the Shuaiba DCC.

Replacements and upgrades involve:

- Extension of the existing SCADA system in the Shuaiba DCC to build up and integrate the NCC database.
- Replacement of significant parts of the telecommunication system to build up a reliable communication network/backbone.
- Data concentrator installment.
- Replacement of existing RTUs that cannot be upgraded with compatible telecommunication protocol interfaces, at 275/132 kV substations supervised by the NCC.

3.2 Stage 2: Realization of Dedicated Emergency Functionality for the NCC with Basic SCADA Tasks

In addition to Stage 1, the Inter Control Center Protocol link (IEC 60870-6 TASE2/ICCP) is used for automatic and online updating of the DCC with the NCC's data and information. The online updates need modifications and/or upgrading for the NCC and DCC. For cost-efficient maintenance, it is recommended that stages 1 and 2 be implemented in parallel.

4 Proposed Multi-Site System

The disadvantage of the present communication link configuration (Fig. 1) includes the isolation of the RTUs that are controlled by the respective DCCs. In the case of a DCC outage or an emergency situation such that the use of the respective DCC location is not possible, the operation of the outstations is discontinued, and data and information transfers between the NCC and DCCs are cut.

Applying the measures proposed in the NCC emergency system in Stage 1, Fig. 3 shows a configuration that is proposed to overcome such RTU isolation.

RTUs are assigned to the communication backbone either directly using IEC 60870-5-104 or via data concentrators (DCs) (with protocol conversion to IEC 60870-5-104). As a result, the communication backbone does not carry any proprietary protocols; those are handled on the lower levels by the DCs.

In this configuration, any control center (NCC or DCC) has access to any RTU data connected to the communication backbone via TCP/IP routing. The communication backbone is also used for interconnection between the control centers via ICCP protocol. This structure supports the objective to relieve the system, as much as possible, of manufacturer-specific influences. Thus, any future modifications in RTU equipment will not affect the system structure, because it is handled at the DCs level.

Given the proposed setups for the NCC emergency system and backup, the NCC and DCC configurations must also be open and flexible for eventual communication with other future control centers in Kuwait, e.g., from generation and distribution companies; with other organizations, e.g., regulatory authorities, market operators; and specially with control centers in neighboring countries (e.g., Gulf States Interconnection ICC).

5 Conclusions

This work proposes configurations for emergency and multi-site control center systems that are specifically designed for Kuwait's control center hierarchical structure. The objectives of these setups are to enhance operational security and provide a backup for the SCADA systems.

Operational security is achieved via the establishment of an emergency NCC. By expanding an existing DCC, i.e., Shuaiba DCC, which has the systems most compatible with the present NCC systems (Fig. 2), an emergency NCC can be developed to handle normal NCC operations.

The backup setup can be established by developing a communication ring backbone (Fig. 3). Hence, in the case of outage of any DCC, an emergency system shall be in place to cover the functions of the failed DCC.

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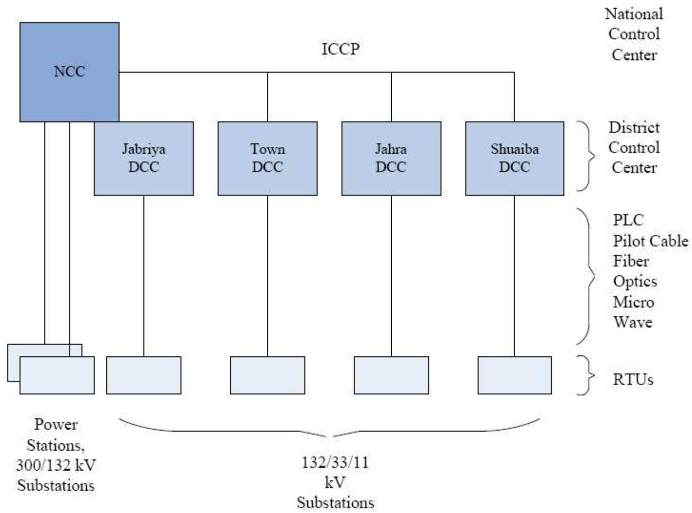

Fig. 1. Present control center structure in Kuwait.

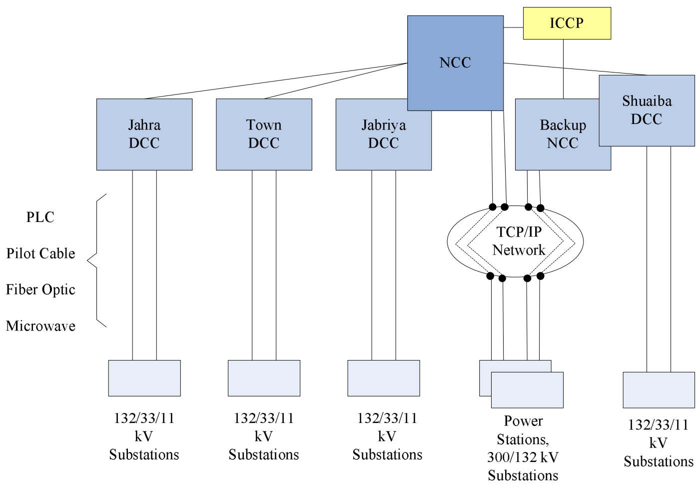

Fig. 2. Configuration of emergency NCC system.

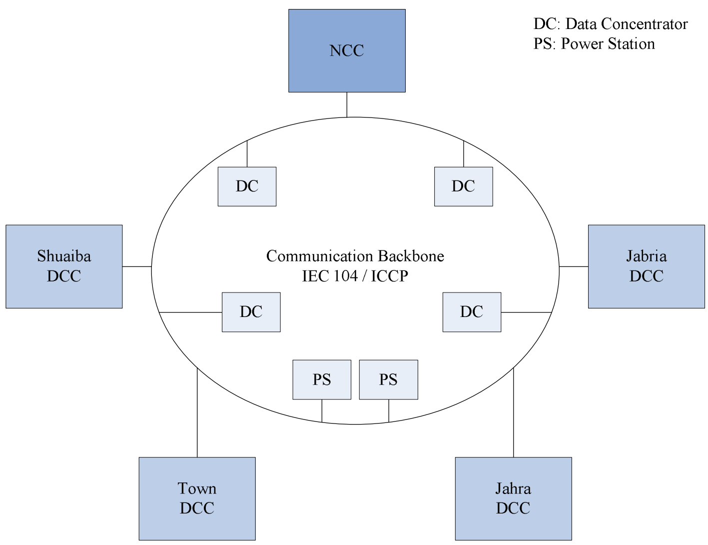

Fig. 3. Proposed configuration of the control center structure.