REACTOR PROTECTION SYSTEM REFURBISHMENT AT PAKS

HETZMANN, Albert
I&C Director
Paks Nuclear Power Plant
Paks, Hungary

TÚRI, Tamás
Project Manager
Paks Nuclear Power Plant
Paks, Hungary

1. Introduction

According to our knowledge, the Paks Nuclear Power Plant is the first operator to undertake such modernisation of the safety I&C systems which, beside modifying the I&C technology and replacing it with a more modern one, will on the one hand change the structure of the safety I&C, and on the other hand change also the functionality of the system in justifiable cases. Changing the I&C technology means the implementation of the logics presently based on relay circuits by using up-to-date digital tools, whereas the modification of the system structure means the integration of the existing autonomous safety subsystems into a single three-channel system. The refurbishmen also facilitates to reveal the inadequacies of the original algorithms by performing adequate performance analyses. The new safety system will implement the refurbished actuation algorithms verified item-by-item for the scope of the modifications and approved and licensed as a whole.

2. Major milestones (Table 1)

The history of the refurbishment starts from the GRS study issued in 1989. That study is the safety review of Unit 5 of the Greifswald NPP, which contains essential statements concerning the safety I&C systems as well. As a result of the study, the nuclear power plant initiated internal reviews partly by analysing the operational experiences, partly by inspecting the operating systems.
Outstanding among the reviews is the evaluation made by Siemens in 1992, which addresses mainly fast reactor shutdowns, but contains statements regarding the Emergency Core Cooling System, too. The study concluded that the fast reactor shutdown system does not meet the single failure criterion, and raised the issue of deficient functional diversity.
In the first half of 1993 the Safety and Economic Establishment of the Refurbishment was completed. That study was the basis for the decision of the NPP management to conduct a limited bid invitation procedure. The invited bidders were Cegelec, Merlin-Gerin, Siemens and Westinghouse.
The Invitation for Bids was issued in autumn 1993. The technical basis for the Invitation for Bids was the document called Task Plan. The evaluation of the bids was performed by involving international consultants (AECL, IVO, PPA) beside the specialists of the NPP. The evaluation was completed in the first quarter of 1994.
The preliminary investment program was developed at the same time. Based on the evaluation report and the investment program the management of the NPP made a decision to continue the preparatory activities after selecting the best two bids. The former team was then replaced

by the project organisation operating presently. Approximately 1 year of joint preparatory work was started involving the two pre-selected companies (Grouppe Schneider and Siemens), which was aimed at producing a detailed customer requirement package and the specifications by the respective companies.
On the completion of the contract activities of the two suppliers, we applied for a Statement by the Authority as to the licensibility of a completely digital three-channel I&C system at the Paks NPP. Having received a positive answer from the Authority, a more precise, revised investment program was submitted to the NPP Board of Directors.
In accordance with the decision of the Board of Directors, a new round of the invitation for bids started on 29. December 1995. That invitation for bids was also limited, involving Grouppe Schneider, Siemens and Westinghouse.
The bids arrived at the end of the first quarter of 1996, whose evaluation was performed by involving international consulting companies again. That evaluation was performed in a more formal way considering much more aspects. The technical evaluation was performed by involving SZTAKI representing the Hungarian scientific background, AECL of Canada, the Finnish engineering company IVO and the Swiss consulting company COLENCO. Hungarian foreign trade and financial experts participated in the commercial evaluation.
In order to minimise the economic risks, signing the supplier's contract was made dependent by the NPP on possessing the principal system license issued by the Authority. Therefore an application was submitted to the Authority parallel to the evaluation. The technical basis for the application was still the supplier-independent technical volume of the Invitation for Bids.
Bid evaluation was completed in the spring of 1996, and the investment program specifying also the exact prices was drawn up. The revised investment program of the Project was approved by the General Assembly of PA Rt. in May 1996.
The selection and post-qualification of the winner was followed by contract negotiations. The principal system license was received in the middle of 1996, facilitating the signing of the supplier's contract between Siemens AG and PA Rt. for the refurbishment of the reactor protection system on the 4 Units of Paks NPP on 17. September 1996.

3. Project Preparation Phase

A determinant phase of the technical preparation work was the Preliminary Preparation Phase. The engineering activities performed in this phase provided the basis for the customer's requirements. These requirements have underlain the second round of suppliers' competition as well as the principal license of the refurbishment.
In the period from April 1994 and the summer of 1995, intensive trilateral work was performed to develop the detailed requirements and specific technical solutions for the Reactor Protection System Refurbishment. In accordance with the schedule accepted by all the three parties, first the supplier independent package of the customer's requirements was developed, followed by the development of the specifications by the respective potential suppliers demonstrating the fulfilment of the requirements using their own equipment.
The development of customer's requirements was carried out in on-going bilateral consultations. During these consultations the suppliers provided assistance in forming the structure of the set of requirements and the content of the individual documents with their comments. Thus a complete, not over-specified requirement package of high standard meeting international standards at the level of modern technology seemed viable.
Within the customer's requirement package, the specification of functional requirements was of outstanding importance. Based on the findings of the AGNES (Advanced and General Evaluation of Nuclear Safety) Project completed in 1993, the document defining the

functional diversity requirements through the analysis of Postulated Initiating Events was prepared. In order to eliminate the deficiencies in diversity, the description defining the functionality of the new system based on the application of the summarised operational and international experiences was compiled. That functional description served as a basis for the development of a formal high-level synoptical logic diagram and I/O database. The necessity of modifications specified in the functional documents was demonstrated through case-by-case analyses.
The specifications of the respective suppliers confirmed the feasibility of the customer's requirements.
The structure of the project documents developed during these activities is shown in Fig. 1. The Quality Assurance Plan and the Development Plan required by ISO 9000 is fitted under the internal regulations of the NPP. The Technical, QA, Investment and Authority document packages are controlled by these two high level documents. The structure of the technical document package follows the life cycle defined in the Development Plan. Thus there are requirements, specifications and the concerned technical design and program documents are to be developed later. The Requirement package includes general technical requirements, detailed technical requirements, functional requirements and analyses.
The QA document package includes the technical QA documents such as the V&V Plan for the Project, the individual verification programs and reports, as well as the procedures controlling the project proceedings.
The Investment document package contains the Investment Program, the cost/schedule plans and the contracts.
The licensing document package includes the correspondence with the Authority, applications and Authority decisions.

4. The life cycle of the Project

The life cycle of the project (see Fig. 2) has been prepared by applying the life cycle published in IEC 880. Considering that the stipulations of IEC 880 are regarded as requirements by the NPP, the major steps of the life cycle therein should be adapted for the refurbishment project as a whole. Therefore the missing interfaces with the NPP environment were added. Unified control requirements were set up for the tasks of each branch of the resultant three-branch life cycle.

The life cycle is divided into four major phases: Preparatory Phase, Design and Manufacturing Phase, Installation and Commissioning Phase and Operation Phase. Each phase has been divided into steps in order that the interfaces between the tasks could be demonstrated. The steps are further refined at the commencement of the given phase. The basic principle is to show all the tasks together with the responsible organisation, exact task definition and the method of verification at the commencement of a phase. It means that the division of the steps due in the given phase shall be available at the commencement of the phase. The elementary task is sufficiently defined to ensure the performance of its individual verification.

The Development Plan merely expands on the life cycle in a way that every phase, step and task is described in an identical structure. The input information (the list of documents to be used), the expected results (list of output documents or products), the precise description of the activity and the organisation responsible for execution are defined. The development Plan is a living document, which means that the clarification of the tasks to be performed is always possible in the knowledge of the outputs from the development process. It is possible that

more precise definition or modification of some tasks is required in the progress of the project. It is necessary to follow these changes, since the Development Plan is one of the most important documents of the project management. The V&V Plan addresses the control of the activities defined in the Development Plan, and the same activities are scheduled in the time schedules.

5. Time Schedule

The time schedule for the implementation (see Fig. 3) has been prepared for 4 units. The activities are scheduled so that they could fit into the planned outage activities considering the schedules of other large NPP projects and safety enhancement measures. In order to reduce the volume of work to be performed during the last planned outage prior to commissioning, pre-installation and site preparation activities are planned partly to be performed during preceding outages, partly on operating units. Table 2 shows the scheduling of pre- and post-installation activities assigned to the outages of the 4 units.

6. Licensing

In Hungary, a multistage licensing process has been developed for handling the modifications of nuclear installations. The authority activities during the progress of the Project and the scope of granted licenses is being adjusted accordingly.
The legal background and the application of the licensing practice used during earlier backfits at the NPP raised several questions during the life of the project. A number of discussions between the management of the NPP and the Authority were required in order to formulate an optimal licensing process adjusted to the Project.
According to our experiences discussions of technical issues between the Authority and the NPP specialists are indispensable. Such discussions provide the authority inspectors insight into the development of the technical solutions, which simplifies the authority review of large technical volumes attached to the individual license applications. At the same time the NPP specialists can become acquainted with and consider authority requirements before the preparation of the applications.
Within the licensing process the licensing of the I&C equipment backfit and the structural modification is handled separately from the licensing of the functionality changes. The principal license for the equipment technology and the new system structure was issued by the Authority on 12. July 1996.
The functionality changes will be licensed after the development of the finalised functional requirements (functional description, formal synoptical logic diagrams and I/O database) and the demonstration of the adequacy of the modifications.
The licensing process includes the construction license for the pre-installation and preparation activities.

MILESTONES OF THE RPS REFURBISHMENT PREPARATION	
Issuance of the GRS Study of Greifswald Unit 5	1989
Paks NPP Internal Investigations and Operational Experiences	1991-92
Safety Assessment of RPS (SIEMENS)	1992
Approval of the Safety and Economic Analysis of the Refurbishment	1993. June
Issuing the Invitation for Bids (Task Plan)	1993. August
Evaluation of the Bids	1994. March
Preliminary Investment Program	1994. March
Preselecting Two Potential Vendors	1994. April
Forming the Reactor Protection System Refurbishment Project	1994. June
GROUPE SCHNEIDER, SIEMENS Contracts for the Project Preparation Phase (PPP)	1994. Sept.
Customer Requirements Issued	1994. Dec. 15.
Issuing the Suppliers' System Specification Closing up the PPP Work	1995. June-July
Application for Authority Statement	1995. June 15.
Authority Statement	1995. Sept.
Investment Plan For Approval of PA Rt's General Assembly	1995. Dec. 14.
Invitation for Renewed Bids (Siemens, Groupe Schneider, Westinghouse)	1995. Dec. 29.
Submitting the Bids	1996. March 14.
Application for Principle System Licence	1996. April 22.
Evaluation of the Bids	1996. April 30.
Updating of the Investment Program	1996. May 3.
Principle System Licence	1996. July 12.
Signing the Contract	1996. Sept. 17.
Kick-off Meeting	1996. Sept. 30.

Table 1.

Milestones

Installation on the Units

	1997	1998	1999	2000	2001	2002	2003
Pre installation 1	1	2	3	4			
Pre installation 2		1	2	3	4		
Installation			1	2	3	4	
Disassembling				1	2	3	4

Pre installation 1: **Place preparation,**
Cable ways in the hermetic area
Hermetic penetrations
Steam generator impulse lines

Pre installation 2: **Place preparation**
Cable ways
Cabling

Installation: **Installation**
Commissioning

Disassembling: **Removal of the old system**

Table 2.

Installation on the Units

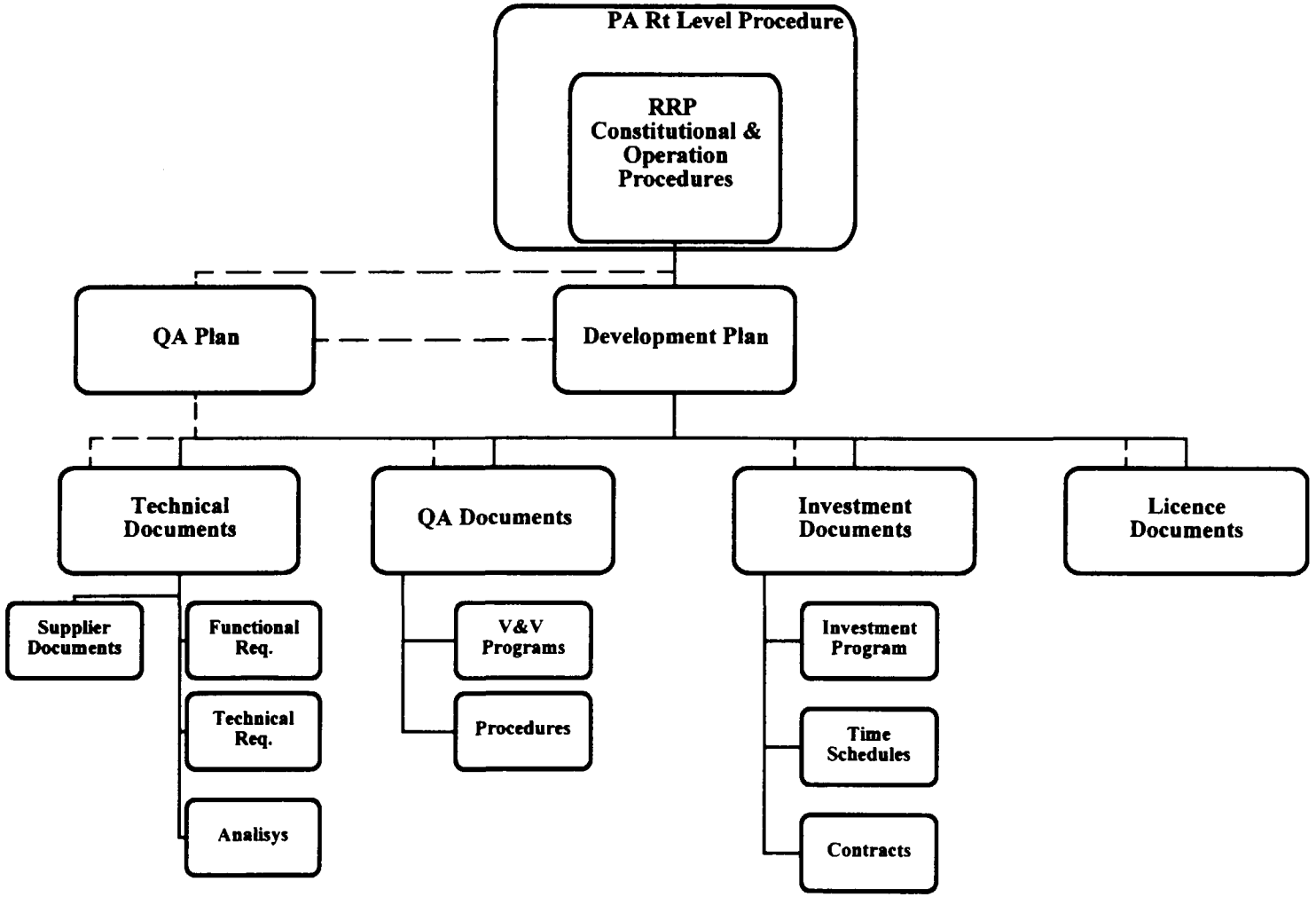

Figure 1.

RRP Documentation Order

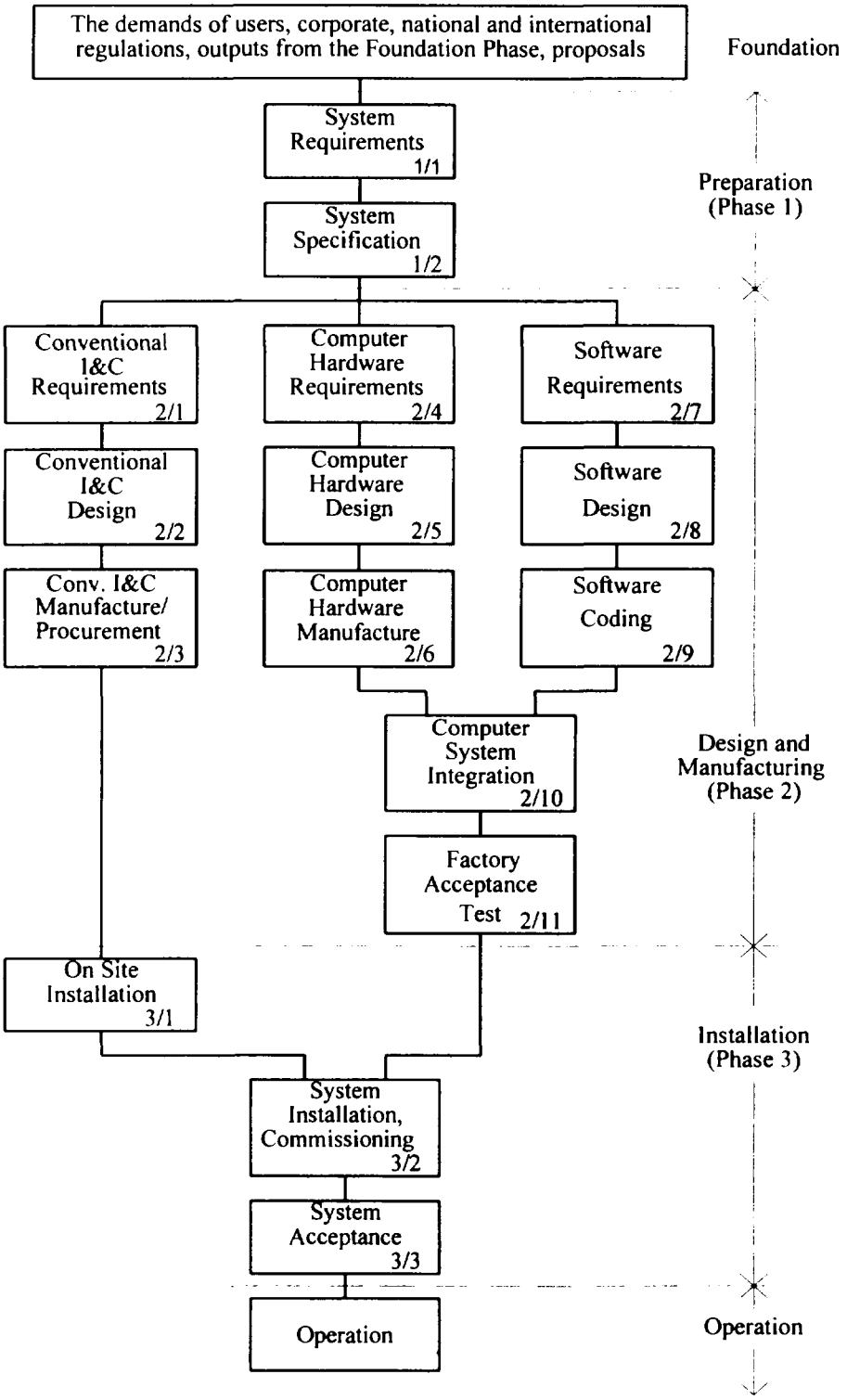

Figure 2.

The Life Cycle of the Refurbishment

HIGH LEVEL TIME SCHEDULE

ID	Task Name	Duration	Start	Finish
1	Unit 1.	737d	'96 Sep 17	'99 Jul 14
2	1. System design	428d	'96 Sep 17	'98 May 07
3	2. Manufacturing	179d	'97 Oct 27	'98 Jul 02
4	3. Factory Acceptance Test	130d	'98 Jul 22	'99 Jan 19
5	4. Installation, Comissioning	551d	'97 May 02	'99 Jun 11
6	5. Pilot run	23d	'99 Jun 14	'99 Jul 14
7	6. Outage in '99	35d	'99 Apr 26	'99 Jun 12
8				
9	Unit 2.	593d	'98 Jul 31	'00 Nov 07
10	1. System design	218d	'98 Sep 21	'99 Jul 21
11	2. Manufacturing	179d	'99 Mar 29	'99 Dec 02
12	3. Factory Acceptance Test	85d	'00 Jan 17	'00 May 12
13	4. Installation, Comissioning	569d	'98 Jul 31	'00 Oct 04
14	5. Pilot run	23d	'00 Oct 06	'00 Nov 07
15	6. Outage in 2000	37d	'00 Aug 16	'00 Oct 05
16				
17	Unit 3.	566d	'99 Jul 09	'01 Sep 07
18	1. System design	215d	'99 Aug 02	'00 May 26
19	2. Manufacturing	180d	'00 Jan 31	'00 Oct 06
20	3. Factory Acceptance Test	85d	'00 Nov 14	'01 Mar 12
21	4. Installation, Comissioning	542d	'99 Jul 09	'01 Aug 06
22	5. Pilot run	24d	'01 Aug 07	'01 Sep 07
23	6. Outage in 2001	37d	'01 Jun 14	'01 Aug 04
24				
25	Unit 4.	570d	'00 Apr 03	'02 Jun 07
26	1. System design	220d	'00 Apr 03	'01 Feb 02
27	2. Manufacturing	180d	'00 Oct 09	'01 Jun 15
28	3. Factory Acceptance Test	85d	'01 Aug 14	'01 Dec 10
29	4. Installation, Comissioning	542d	'00 Apr 07	'02 May 06
30	5. Pilot run	24d	'02 May 07	'02 Jun 07
31	6. Outage in 2002	37d	'02 Mar 14	'02 May 04

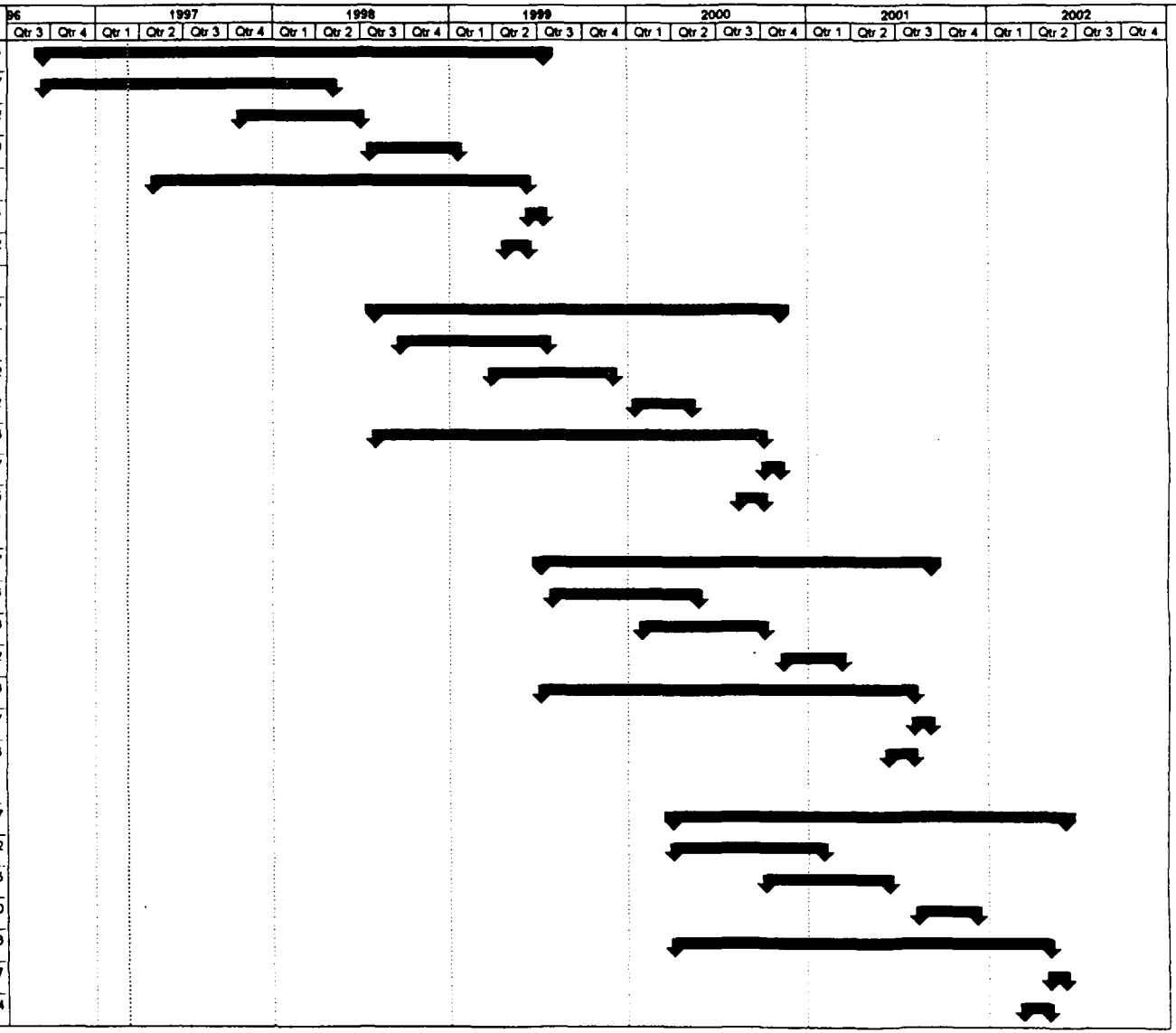

Figure 3.