

FULL AUTOMATION OF STEAM SUPPLY IN FUTURE MODULAR FCDS PLANTS, USING A PC-BASED CONTROL SYSTEM

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Abstract

The design trend in developing new, and expanding developed geothermal fields use Modular Fluid Collection and Disposal System (FCDS) and Power Plants due to the rugged terrain and/or ample distance that makes long pipelines uneconomical to connect these plants to the main initially developed site. As this small (usually 20MWe) Modular Plants increase in a field, unmanned operation of its FCDS is a good economical option. This would require full automation using a PC-based SCADA, wherein a supervisory computer would automatically log and send data to the main plant for monitoring and recording purposes. Such system should be designed to be fail-safe. Maintenance and plant trip troubleshooting are then catered to by personnel from the main site (i.e. Ohaaki Plant, NZ). A plant trip of one module may not have a significant effect on the total capability of the grid it is serving due to its small capacity. The modular plants, which were intended to be base-load plants, are affected by the total loading of the main plant and the grid, hence it has been experiencing load fluctuations.

The scope of this paper covers only the basic automation of the wellhead motorized valves, making it load-following. Good control of the wellhead motorized valve results in a minimum wastage of vented steam and ultimately, the longevity of the production field. The proposed system is PC-based and employ "intelligent" instruments which are readily available and are now in use in the industry. One major feature of the system is the use of discrete control signals instead of analog signals, which would eliminate "hunting" due to the time-delay in the delivery of steam from the wellhead to the separator.

1.0 INTRODUCTION

Why automate? The obvious answer would be to reduce production cost by reducing manpower. This comes from the impression that machines could duplicate repetitive human activities. However, it has been experienced that automation could not only duplicate, but in many cases could do a better job than could be done manually (Bohannon, 1984), and could prevent exposure of humans to hazardous areas. Thus, increased efficiency, productivity and safety has become the main justification for automating processes. Computer-based instruments have enhanced the capability of automatic control, making it possible to propose fully automated, unmanned process plants, geothermal systems included. An example of this is the Castle Rock Springs area of the Geysers field in California (Kumataka and Bayard, 1982). Future modular FCDS plants, with its remote location and small capacity, are prime candidates for a fully automated computer-based control system. Maintaining an operating crew in a remotely located area entails high cost and safety hazards. An unmanned modular plant could be remotely monitored by an operator in the main plant using computer communications.

The main hindrance in the full automation modular FCDS plants is the variable load it has been experiencing. Automating the output of a production well, controlled by a motorized valve have posed a major problem. It is the solution to this problem that is addressed in this paper. Once this step has been taken, the rest of the steps towards full automation would easily be implemented. The topics discussed in this paper includes: the proposed control well automation scheme for Palinpinon-1 (PNOC-EDC Internal Report, 1987) using analog controllers, the reasons why this scheme did not work, the improvements proposed with intelligent controllers using discrete techniques, the simulations done to demonstrate its applicability, and its adaptation to a fully automated Supervisory Control and Data Acquisition (SCADA) system. The descriptions

given are operational for ease of understanding, and complex mathematics and control engineering jargon are avoided.

2.0 CONTROL WELL AUTOMATION USING AN ANALOG CONTROLLER

The operating pressure at the turbine inlet is kept constant using a pressure control loop (Fig. 1). Steamline pressure (at the turbine interface) is measured by a pressure transmitter (PT-01) and transmitted to the interface pressure indicating controller (PIC-01) which compares the measured signal with the desired value or setpoint. A signal which corrects the error between the two is sent to the final control element -- the pressure control valve (PV-01) installed on the blow-off line, which would either open to relieve excess pressure (when the turbine load decreases) or close to add pressure (when the load increases) to the interface line. PV-01 is calibrated in terms of percent opening, with 0% corresponding to a fully closed valve and 100% fully open.

An increase in the load of the turbine which is more than the reserved steam vented in the blow-off line would cause PV-01 to fully close. When this happens, additional steam supply would have to be provided from the production wells with wellhead motorized valves (MV). Currently, this action is done remote manually both in the main and modular plants.

Automating the steam supply involves the control of the production well motorized valve (Fig. 1). The percent opening of PV-01 is sensed using a position transmitter (XT-02). When PV-01 is near 0% or fully closed position (which would mean additional steam supply is needed), PIC-02 would send a signal to the motorized valve (MV) to open, adding more steam into the system. On the other hand, if PV-01 would have a large opening the motorized valve is automatically closed. Such control system would seem satisfactory, but when a similar scheme was proposed and tested in Palinpinon 1, "hunting" was experienced. Both PV-01 and MV were oscillating - a constant opening and closing of the valves, in other words, the system did not stabilize.

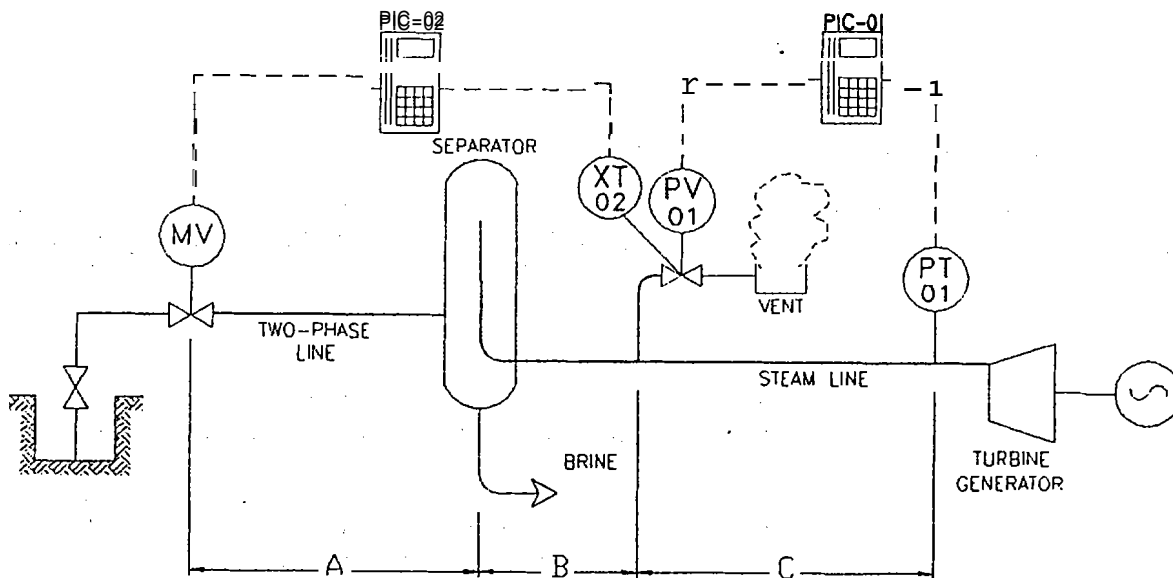


Figure 1. Automatic load-following motorized valve (MV) control using an analog controller.

The first factor which makes the analog control strategy fail is the distance between the sensing point (XT-02) and the action point (MV). In control engineering, it is termed as *deadtime lag*, expressed with the equation,

$$T_d = D_{sc} / V_f \quad (1)$$

Where T_d is the deadtime lag, D_{sc} the distance between the sensing point and the action point, and V_f is the velocity of the fluid. In Fig. 1 D_{sc} would be equal to $A+B$. However, XT-02 is actually sensing the position of PV-01, which is being controlled using the signal from PT-01, therefore the total D_{sc} would be equal to $A+B+C$. In the Nasuji Modular FCDS for example, D_{sc} is about 825 meters. In an experiment conducted, T_d was measured to be approximately 10 secs. This experiment was done by taking the time from when MV was actuated (moved) to the time when a change in pressure was sensed at PT-01, with the load constant. Since the sole purpose of actuating MV is to supply steam to cope up with load changes as sensed by PT-01, its effects should ideally be felt at PT-01 immediately. But for example, if it would take 10 seconds for it to reach the sensing point, other load changes (increase or decrease) could happen, even before the steam supply reaches PT-01. The effect of deadtime lag therefore, has to be taken into account to have an effective control system.

The second factor affecting the system is the analog nature of the controller. The analog PIC-02 continuously senses the output of XT-02 and automatically applies a correction signal to actuate MV to the proper valve opening. Because of its continuous nature, it would keep on sensing XT-02 and applying the correction signal to MV, even before its previous correction has made an effect on the system due to the deadtime lag. Therefore it is applying the wrong correction signal at MV to that sensed at XT-02. If we would use the above deadtime lag of 10 seconds (Nasuji FCDS), the only way the controller can apply the correct actuating signal to MV is to wait at least 10 seconds before sensing another signal at PT-01. But since the analog controller continuously senses PT-01 throughout the 10 seconds time span, it is sending unwanted signals to the control system which is considered as noise. When noise is introduced into a control loop, its stability suffers, preventing it from reaching its equilibrium state.

The third factor is the type of measurement XT-02 does. It measures the position of PV-01. Both PV-01 and XT-02 have mechanical parts, which could add another time delay if backlash is present, and precision of measurement would also come into question. For a fully automated system, the probability of failure would increase, since XT-01 would always depend on the reliability of PV-01.

3.0 IMPROVED AUTOMATION SCHEME USING DIGITAL CONTROLLERS

The introduction of microprocessor-based controllers in the industry have tremendously improved the ability to introduce complex strategies in control systems. These "intelligent" controllers are software driven, and aside from having the standard control functions, could also perform numerical computations, logic functions, memory functions, time delay, filtering, etc. Big improvements could be introduced into the control well automation system using digital controllers.

The wellhead MV control loop is now made independent of the blow-off control loop (Fig. 2). This would remove the dependence of the measurement on the reliability of PV-01, and the possible time delay introduced by the blow-off control loop. Instead of measuring valve position, steam flow is directly measured, making it accurate. Steam flow meters employing orifice plates have proven reliable and stable as per experience. These are installed in the steam line on the turbine interface and immediately downstream of the separator. The reserve steam flow on the blow-off line is measured by the flow indicating controller (FIC-02) using the equation,

$$SF_b = SF_s - SF_i \quad (2)$$

Where SF_b is the reserve steam vented by the blow-off, SF_s is the steam flow at the separator measured by FT-02, and SF_i the steam flow at the interface by measured by FT-01. It would now be possible to have minimum amount of steam vented by the blow-off by allowing SF_b to operate in a specific range. For example, if SF_b is to be kept between the limits of 5 to 15 tons per hour (TPH) or 10 ± 5 TPH, once it falls below 5 TPH, FIC-02 would automatically open MV slightly to augment the steam supply, and on the other hand, when it increases to more than 15 TPH, MV closes slightly to reduce steam supply. Small additions and reductions in steam supply could be accomplished by making the action of MV to be time-dependent, instead of position-dependent. For example, FIC-02 could move MV to open for only 2 seconds for each command. In the Nasuji FCDS for example, an 18 inch MV gate valve moves approximately 1/4 inch for a 2 second command.

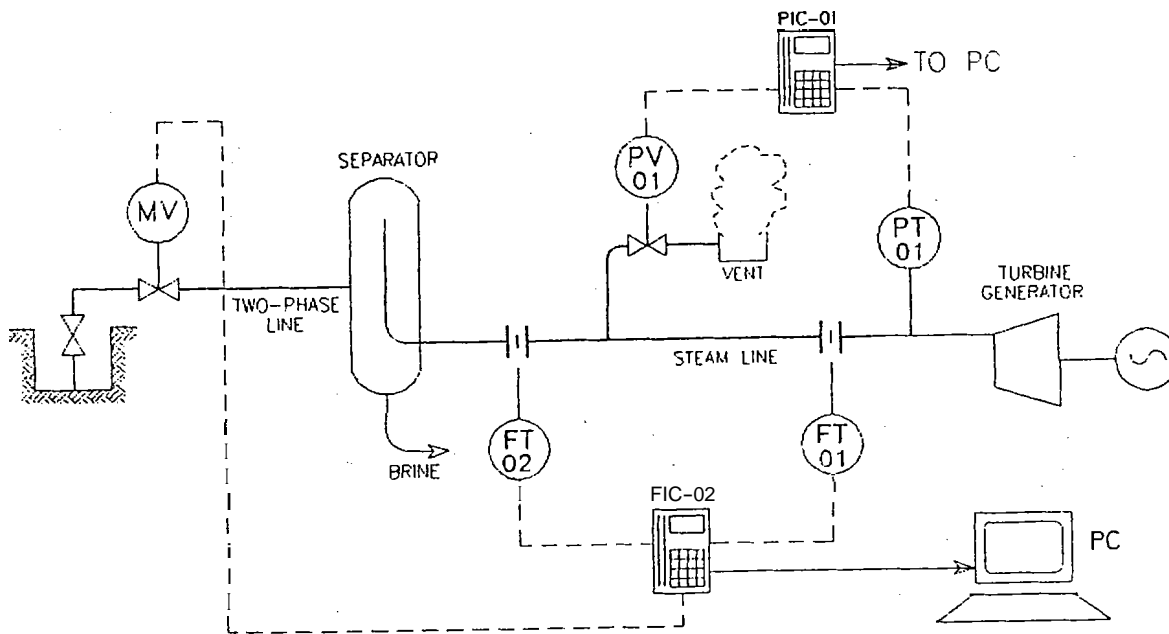


Figure 2. Improved MV control using "intelligent controllers"

By the use of a digital controller, deadtime lag is taken into consideration using discrete-time sampling. SF_b is sampled in a fixed time interval that would allow the action of MV to first take effect (SF_b change) upon the system before sampling again. For example, if the steam added at MV would take 10 seconds to have an effect of SF_b , sampling would be done every 15 seconds to allow the system to stabilize. The output signal to MV is also discrete or specific, since it actuates only at a fixed time duration, for example 2 seconds. Therefore, a properly timed discrete input and output of FIC-02 would make sure that the correction signal to MV is applied to the correct signal sensed at SF_b . Noise due to a wrong signal input to FIC-02 is eliminated. A schematic of the strategy is shown in the block diagram (Fig. 3) below.

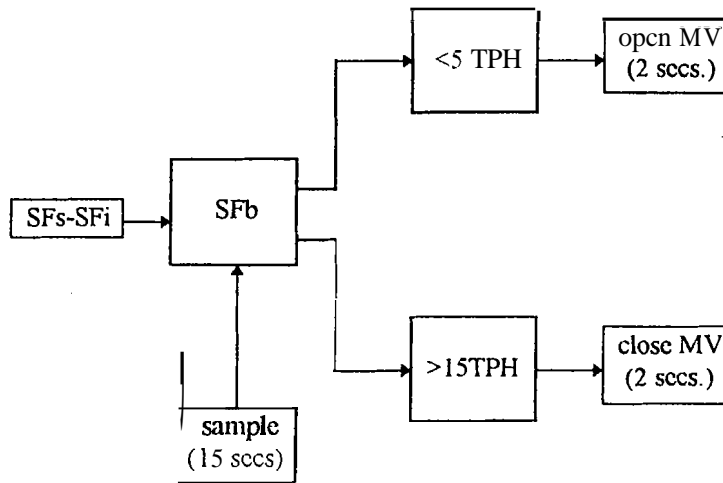


Figure 3. Control strategy of FIC-02.

An added feature in the system is that a trend could be computed for Sfb , and if a fast decrease is recorded, such as when the turbine is still loading towards its maximum, the time duration of the MV action could be increased, say from 2 to 4 seconds, either automatically or by manual input of the operator. This would ensure adequate steam supply for fast rising loads.

What makes the discrete strategy advantageous is that it models more closely what the human operator does. When an alarm sounds to announce a depleted blow-off steam supply for example, he presses the "open" pushbutton of the MV for a few seconds, then wait for an effect on the system, before he decides whether or not it would be necessary to push the button again. His waiting time is equivalent to the discrete-time sampling interval, and the few seconds duration he presses the button is equivalent to the duration of the discrete MV command or actuation. Discrete control strategy therefore, closely duplicates the actions of the human operator.

4.0 RESULTS OF SIMULATION

Manual tests were done at the Nasuji modular FCDS to simulate the action of the discrete controller FIC-02. Both addition and reduction of steam supply were tested. The main objective of the test was to bring up (for addition) or down (for reduction) Sfb to a target range that is between 10 TPH or ± 5 TPH limits. This target range was based on an observed normal fluctuation of Sfs of ± 3 TPH (depending on the production wells on line) and Sfi fluctuation of ± 0.5 TPH at steady load. The procedure was to read or sample Sfb from an indicator every 15 seconds and push the open or close button of MV for 2 seconds if Sfb is not within the target range. The wells on line were NJ4D (55.6 TPH), NJ5D (80.1 TPH), and the motorized valve controlled well OK6 (59.6 TPH at 100% opening). Load range was at 18 to 19 MWe and Sfi at 144 to 147 TPH. The results are shown on Table 1. It is noted that Sfb stabilized within the target range after 6 and 7 MV actuations for steam addition and reduction respectively.

PARAMETERS	ADDITION TEST	REDUCTION TEST
Sampling Interval	15 seconds	15 seconds
Duration MV actuation	2 seconds	2 seconds
Target SFb	45-55 TPH	35-45 TPH
Initial SFb	29 TPH	51 TPH
Final SFb	49 TPH	38 TPH

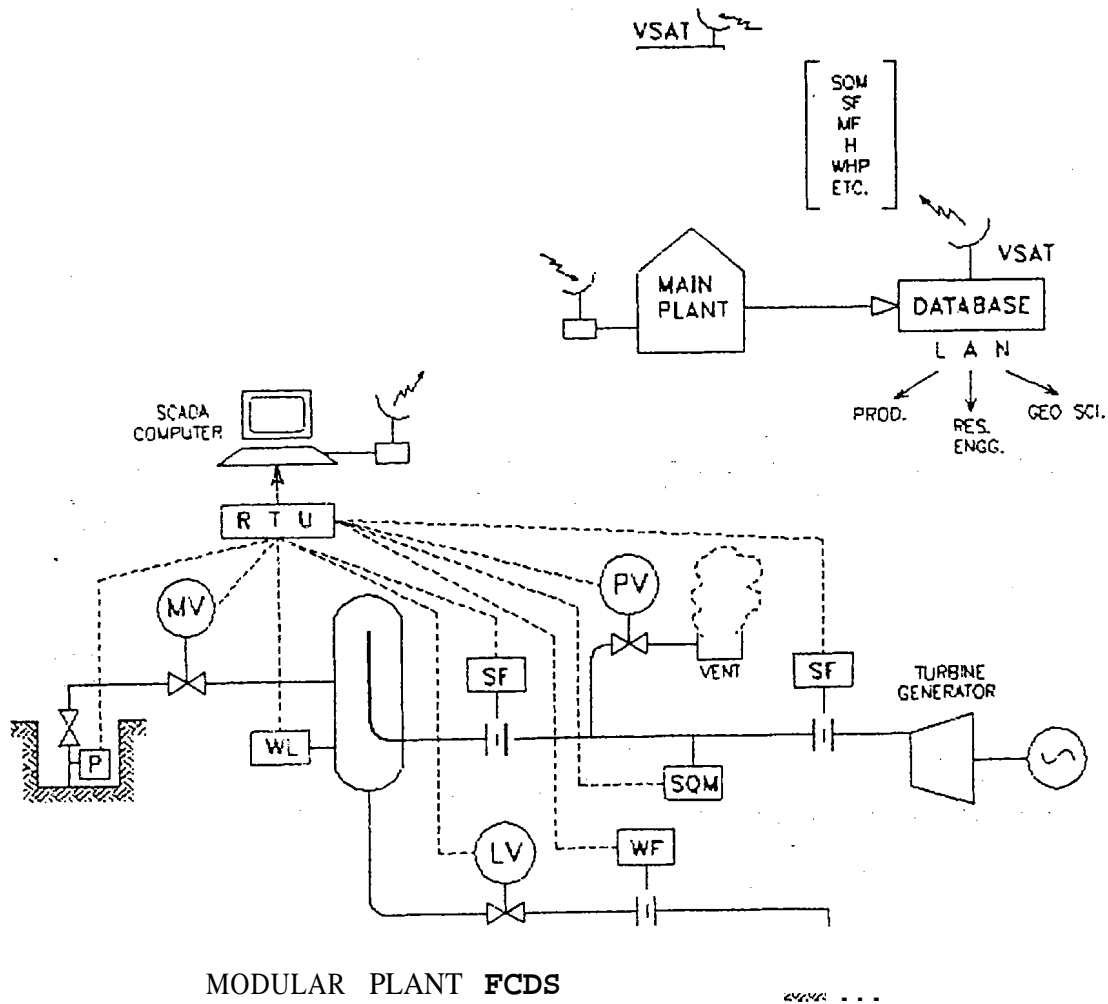
5.0 THE ROAD AHEAD -TOWARDS FULL AUTOMATION

A computer-based automatic control system is not new in the process industry. Although early recorded use was in the late 1950s by Louisiana Power & Light and Tesaco, it was in the years between 1965 to 1970 when its popularity became widespread. During that era, multiple analog controllers were replaced with one centralized digital computer. This scheme, known as Direct Digital Control (DDC), not only optimized plant operations and reduced manpower, but also provided automatic recording of process parameters in its database. These systems were hooked up to creative graphic monitors which could simultaneously display the process schematic and real time data trends. Numerical calculations could also be done automatically and loaded into the database for later retrieval by concerned sections. The DDC however had its own disadvantages, which limited its popularity in medium and small scale plants. Its use of mainframe and minicomputers made hardware and maintenance costs too expensive to justify in smaller processes. Unfortunately, it is these processes that ideally should be fully automated. Advancement in the control system technology introduced another scheme known as the Distributed Control System (DCS). It is composed of analog controllers locally mounted in the field which could communicate with a host computer, usually a minicomputer or workstation size. The controllers could either receive commands from the host, or could work as a stand-alone when the computer or communications are down. Still the DCS was too complex and expensive for small applications. However, it was the forerunner of the SCADA scheme which has become popular today. The SCADA still uses the distributed control principle but has taken advantage of the latest state-of-the-art Information Technology (IT), using Personal Computers (PC) and Data Communications. The first users of SCADA were in the oilfield industry, using a computer located on a control center for monitoring and control of remote production wells, gathering stations and pipelines. Later, it spread to other industries such as power plants, electric transmission lines, water systems, transportation, security systems, etc.

Obviously, the PC-based SCADA is the scheme that is most applicable in fully automating the remotely located modular FCDS. "Intelligent" controllers, which are now available in the market, would be used for automatic pressure and level control, and interface with a PC which would communicate with the main plant for supervision, data logging and recording. Such PC is capable not only of automatically recording field parameters such as pressure, temperature, steam flow, condensate flow and steam quality, but also for numerical calculations such as computing the mass withdrawn, mass injected, field enthalpy and field steam capability. This will also include automatic data logging of bore output measurements and onsite analysis (Morris and Clotworthy, 1993). All the data is stored on its database, and also communicated to the main plant and head office for ease of retrieval by concerned sections. A similar scheme was proposed for the Palinpinon-1 FCDS in 1986 by A. J. Brodic (PNOC-EDC Internal Report, 1986). If a fail-safe plant shutdown interlock is incorporated into the system, plant operators would no longer be necessary. Maintenance, troubleshooting and start-up would be serviced by personnel from the main plant.

The scenario of a PC-based SCADA as applied to modular FCDS plants is shown in Fig. 4. The remote terminal unit (RTU) incorporates the functions of the automatic digital controllers, data loggers and recorders. Data is transmitted to the main plant through a microwave link, where it is stored on a Management Information System (MIS) database. Field personnel from Production, Reservoir Engineering and

Geoscientific sections have an access to the data through a local **area** network (LAN). **The** VSAT link will be used to automatically send **data** to the main office at Fort Bonifacio. Pro-formatted integrated reports will be readily available **from** the MIS.



Nomenclature

- SQM - Steam Quality Monitoring / NCG levels.
- SF - Steam **f**low at separator, turbine interfacc and blow-off.
- WF - Water **f**low at reinjection wells.
- MF - Total mass withdrawal calculated **by** mass balance (SF + WF).
- H - Average field cnthalpy calculated **by** heat balance (MF x H = SF x hg + WF x h_f).
- WHP- Production and reinjection wellhead pressurcs.
- WL - Separator water level.

Figure 4. The Future: SCADA in modular FCDS plants.

6.0 CONCLUSION

The advantages of using “intelligent” controllers employing discrete control signals over analog controllers for steam supply automation can be summarized as follows:

- It models closely the actions done by a human **operator**.
- It can directly compute the blow-off steam **flow** instead of inferring it from the position of the control valve.
- Discrete sampling techniques takes into consideration the deadtime lag problem.
- Discrete time-dependent command to the motorized **valve** (MV) allow **small** and precise addition and reduction of steam supply.
- It can readily adapt to a PC-based SCADA.

Automating the steam supply from the control wells is the most complicated step **towards** unmanned operation. It is hoped **that** the solution presented in **this** paper would lead to the realization of fully automated modular FCDS plants.

7.0 REFERENCES

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