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Turbo Compressor Modelling with Fuzzy Petri net

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Abstract. Gas exploitation, filtration and refinement are the partial of basic and important industries in Middle East countries. Discernment of fluid behavior in various environmental condition and attempt to improve system's safely factor is essential scope of modelling in these industries. Modelling often is been base of mathematical schemes that be complex and difficult to realize for each users. And addition, it unable to present details completely. Petri Net is graphical modelling tool base of mathematical concept that useful for modelling discrete events in dynamic circumference. Although in gas industries with uncertain variables shouldn't be effective. Fuzzy Petri Net is useful for modelling and control of systems with uncertain knowledge. Turbo compressor is one of advantageous equipment in oil and gas industries that in this paper, its operation was modeled with Fuzzy Petri Net. The model illustrates correlation among parameters simply and with finished detail. An addition, obvious discernment of system behavior in various conditions presents that is apprehensible for each user and without the heavy cost of testing is applicable.

Keywords: Refinery gas, Turbo compressor, Fuzzy Petri Net, Surge.

1. Introduction

Refinery industries have important role in countries economic, that dynamism and up to dating of them are vital and considerable [1]. Exploitation, refinery and transmission are correlate divisions of gas industries. In transmission gas field, gas compressor stations have special situation. These stations designed to transmission gas from one location to another with supporting require pressure again pipe friction. These stations constructed each 100 Kilometres through pipe lines and performance theirs acts with predefined process. The process require equipments and installation that turbo compressor as heart of station is primary equipment for compressing gas [2], [3]. Surely, be mention, another process plant such as refinery and petrochemical also use turbo compressor through theirs processes. So it's obvious, with huge numbers of this vital and expensive equipment, modelling and simulation for design operation and maintain is so essential.

Because of this essential, various software and simulation models as processing software (ASPEN, PRO, HYSYS and etc.) created while modelling process parameters with several definite input conditions. Beside, mechanical modelling software such as FLUENT, ABAQUS, ANSYS and etc released to analysis stress, strain, vibration, static and thermal loading and etc [4], [5], [6]. Also some researches in this field with Fuzzy theory were done. As for done activities, relative among processing, mechanically data and modelling results base of fuzzy concepts sense. Another look is from processing regard to another regard, which system is a devise with integration of mentioned parameters. In this paper, we want to present a model which able to deliver operation, utilization, mechanical and control parameters without experiment test and only with defined correlation among variables. An addition, we want to lead to made best states of control, monitoring,

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operation and design with modifying conditions. Development of logicality and effective correlation among variables with Petri net is the other field of this article.

Petri net is strong tool in graphical system modelling base of mathematical description [7]. Logical fuzzy also is an effective technique for modelling systems with uncertain and incomplete data which got with operators information [8]. In this paper, to gain above purposes used fuzzy Petri net for modelling a case study turbo compressor. Heyen (1994) was simulated compressor operation in various conditions dynamically with thermodynamics and fluids equations [9]. Badmus (1996) used mathematical modelling for surge control [10]. Ogaji (2005) in his study was illustrated encountered faults of turbo compressor in each time with fuzzy procedure [11]. Khan (2006) and Erikson (2008) presented mathematical model of centrifugal compressor [12], [13]. Farrahi (2011) had studied error analysis for turbo compressor with mathematical equations [14]. Anyway, not one presented models show parameters affect simultaneously and obvious realization of operation system manner doesn't offer. In this paper, we present a model to show parameters relation simultaneously that has simple recognition caused by graphical demonstration capability and it be able to estimate system behaviour.

2. Modelling and Control

2.1. Fuzzy Petri Net

Petri nets supply a powerful formal modelling method based on a solid mathematical structure while having graphical representation of system models as net diagrams. But with development and rising complication of industrial systems, Petri net unable to solve uncertain and imprecise problems. In order, available researches showed that Petri nets can combine with another theories and techniques such as Object-oriented programs, fuzzy theory, neural network and etc, simply [15], [16]. Today, this Petri net widespread in computer, industrial plants, robotics, systems base on knowledge, and the others engineering applications [17]. FPN was being proposed as 8-tuple: FPN=(P, T, D, I, O, f, α, β), $P=\{p_1, p_2, \ldots, p_i\}$ was a finite set of places; $T=\{t_1, t_2, \ldots, t_i\}$ was a finite set of transitions; $D=\{d_1, d_2, \ldots, d_i\}$ was a finite set of propositions; I and O were the function of set of input and output places of transitions, where I: P→T was the input function, a mapping from transitions to bags of places; O: T→P was the output function, a mapping from transitions to bags of places; f: T→[0,1] was an association function, a mapping from transition to real values between zero and one; α:p→[0,1] was an association function, a mapping from places to real values between zero and one by membership function; β: p→D was an association function, a objective mapping from places to propositions[16], [18]. A transition can be fired under the condition that the degrees of the truth (Certainty Factor: CF) of all its input places are not null and greater than certain threshold values. When transition t fires, the token values of its input places are used to calculate the token values of its output places according to certain rule-types [19]. General types of fuzzy rules are:

R1: If d_j, then d_k, (CF = μ)
R2: IF d_{jl} and d_{j2} and … and d_{jn} THEN d_k (CF = μ)
R3: IF d_{j1} or d_{j2} or… or d_{jn}, THEN d_k (CF = μ)
Figure (1) shows the types of fuzzy rules:

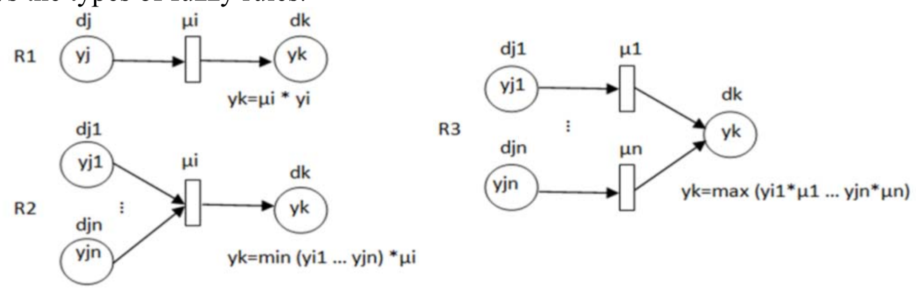

Fig. 1: types of fuzzy rules[19].

2.2. Turbo Compressor

To raise pressure, refined gas with unit input valve transmission to gas compressor while mounted parallel of each other. In each unit an anti surge control valve installed to protect compressor again dangerous surge phenomenon. Anti surge line is connected input and output of compressor with pipe line to transmission flow from output to input. Surge is a dangerous phenomenon while occur when shortage flow in output appear and cause intensive vibration in compressor and turbine [2], [3], [20].

2.3. Discussion and Conclusions

Diagram of the gas compressor station is shown in figure (2).

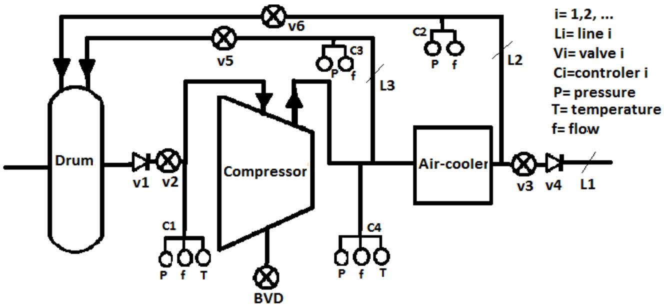

Fig. 2: diagram of compressor gas station.

The following rules are got with regard to information operators and system acts:

R_1: if p_1 OR p_2 OR p_3 then p_{15} (CF= μ_1, μ_2, μ_3)
R_2: if p_4 OR p_5 then p_{17} (CF= μ_4, μ_5)
R_3: if p_{14} then p_{20} (CF= μ_{12})
R_4: if p_{15} OR p_{17} OR p_{16} OR p_{20} OR p_{18} then p_{21}
R_5: if p_6 AND p_7 then p_{19} (CF= μ_6)
R_6: if p_8 AND p_9 then p_{19} (CF= μ_7)
R_7: if p_{10} then p_{19} (CF= μ_8)
R_8: if p_{11} OR p_{12} OR p_{13} OR p_{19} then p_{22}
R_9: if p_{22} then p_{24} (CF= μ_{18})
R_{10}: if p_{24} AND p_{23} then p_{26} (CF= μ_{19})
R_{11}: if p_{24} AND p_{25} then p_{27} (CF= μ_{20})
R_{12}: if $p_{19\text{-}2}$ AND $p_{19\text{-}3}$ AND $p_{19\text{-}4}$ then $p_{19\text{-}12}$ (CF= $\mu_{19\text{-}2}$)
R_{13}: if $p_{19\text{-}2}$ AND $p_{19\text{-}5}$ AND $p_{19\text{-}6}$ then $p_{19\text{-}13}$ (CF= $\mu_{19\text{-}3}$)
R_{14}: if $p_{19\text{-}2}$ AND $p_{19\text{-}7}$ AND $p_{19\text{-}6}$ then $p_{19\text{-}4}$ (CF= $\mu_{19\text{-}4}$)
R_{15}: if $p_{19\text{-}2}$ AND $p_{19\text{-}1}$ then $p_{19\text{-}10}$ (CF= $\mu_{19\text{-}1}$)
R_{16}: if $p_{19\text{-}10}$ OR $p_{19\text{-}9}$ then $p_{19\text{-}15}$(CF= $\mu_{19\text{-}15}$)
R_{17}: if $p_{19\text{-}15}$ then p_{26} (CF= $\mu_{19\text{-}10}$)
R_{18}: if $p_{19\text{-}12}$ AND $p_{19\text{-}11}$ then $p_{19\text{-}16}$ (CF= $\mu_{19\text{-}7}$)
R_{19}: if $p_{19\text{-}16}$ then $p_{19\text{-}18}$ (CF= $\mu_{19\text{-}11}$)
R_{20}: if $p_{19\text{-}18}$ AND $p_{19\text{-}17}$ then p_{26} (CF= $\mu_{19\text{-}12}$)
R_{21}: if $p_{19\text{-}18}$ AND $p_{19\text{-}19}$ then $p_{19\text{-}20}$ (CF= $\mu_{19\text{-}13}$)
R_{22}: if $p_{19\text{-}13}$ OR $p_{19\text{-}14}$ then $p_{19\text{-}9}$ (CF= $\mu_{19\text{-}8}$, $\mu_{19\text{-}9}$)

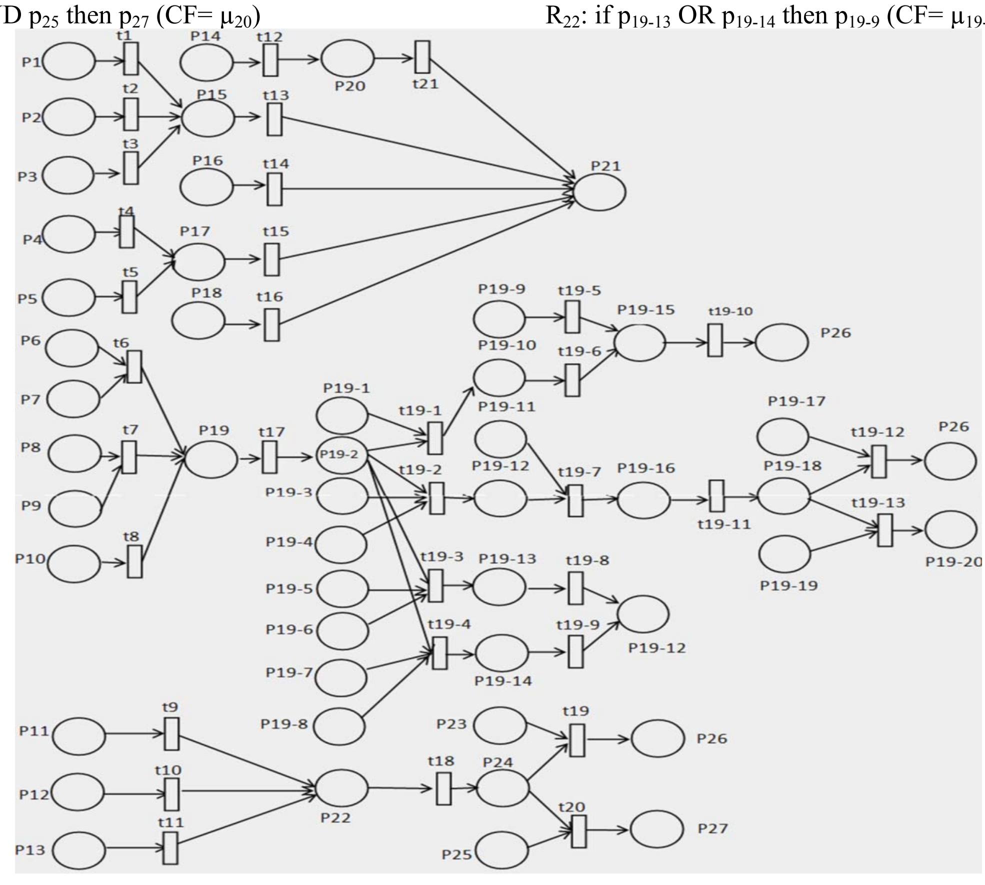

Fig. 3: Fuzzy Petri Net for compressor (modelling & control)

Fuzzy Petri net for the compressor based on the proposed rules is shown in Figure (3).

Table (1), shows the list of places for proposed rules; each place is equivalent to a fuzzy predication.

Table 1: list of places

P1	High input temperature	P15	High temperature out of compressor
P2	High pressure	P16	High pressure in out of compressor
P3	Mechanical error	P17	low temperature in Air cooler
P4	Low flow in Air cooler	P18	Exist oil in external gas
P5	Low pressure in Air cooler	P19	Active Surge mode
P6	Low pressure in inlet of compressor	P20	High humidity
P7	Low flow in inlet of compressor	P21	Damage of compressor and device
P8	Low pressure in out of compressor	P22	Increase vibration compressor
P9	Low flow in out of compressor	P23	High vibration
P10	High contamination in Propeller	P24	Decrease speed
P11	Critical speed of compressor	P25	Low vibration
P12	High speed of compressor	P26	Compressor Shut down
P13	Error in setup device	P27	Go on
P14	High level liquid in storage	P28	----
P19-1	Error because of compressor failure or don’t open valves	P19-11	Low flow
P19-2	Active surge mode (duplicate)	P19-12	Open valve 6
P19-3	Low input pressure	P19-13	Semi closure of valve 3
P19-4	Low input flow	P19-14	Full Closure valve 3
P19-5	Low-low input pressure	P19-15	Open BVD
P19-6	Low-low input flow	P19-16	Open valve 5
P19-7	Too Low input pressure	P19-17	Low output flow
P19-8	Too Low input flow	P19-18	Checked controller of compressor
P19-9	Open the Input/output Air cooler valve	P19-19	Sufficient flow
P19-10	Surge	P19-20	The compressor work

Table (2), shows the results for the three categories of input data. Values assigned to each place must be converted to fuzzy value by membership function. Fuzzy outputs must also be defuzzification.

Table 2: results for three phases

		1	2	3		1	2	3
liquid level in storage		0	0	0	input pressure	50	20	60
air cooler temperature		120	120	120	input flow	550	250	580
Flow- air cooler		550	400	580	input temperature	30	30	30
pressure temperature		85	50	87	output pressure	85	50	87
exist oil in external gas		0	0	0	output flow	550	400	580
open input/output air cooler valve		0	0	0	output temperature	120	120	120
vibration		0.5	1	2	exist contamination in propeller	0	0	0
mechanical error		0	0	1	critical speed	0	0	1
error because of controller failed or controller valves		0	1	1	speed	2000	2000	1800
error in setup device		0	0	0	------	-----	----	---
	Shut down	Stage1	0.12	Stage2	0.95	Stage 3	0.15	
results	damage		0.05		0.5		0.92	
	work		0.85		0.02		0.07	

Fuzzy Petri nets are suitable tool to model and control uncertain systems. In this paper, results of turbo compressor operation with FPN modelling tool compared with empirical results. According to this comparison we realize, FPN tool had high capability for modelling industrial systems with high complexity as well as simplicity and be comprehensible and Implementation of this model without testing and the heavy cost of it, is applicable. An addition by comparing with mathematical model it presents completely detail and no need to use complex mathematical equations. This modelling method is extensile to the others refinery divisions. Table (3) shows the comparison modelling tools.

Table 3: Comparison Modelling Tools

Tools / features	Show correlation between variables	Ability control	Simplicity in modelling	real time	Knowing the Process concepts	Modelling based on experimental results	Type modelling tools
ASPEN- HYSYS	Mean	No	Mean	No	Yes	Mean	Software
FLUENT	Mean	No	No	Yes	Yes	No	Software
ANSYS	Low	No	Mean	No	Yes	No	Software
ABAQUES	Low	No	No	Yes	Yes	No	Software
Mathematical	High	No	No	No	Low	No	Basic method
FPN	High	Yes	High	Yes	No	Yes	Basic method

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