

# Contents

## Part I Theoretical Aspects

<b>1</b>	<b>Introduction</b>	<b>3</b>
1.1	Micro/Pico Hydroelectric Power Stations	4
1.2	Micro/Pico Hydraulic Turbines	6
1.2.1	The Pelton/Turgo Turbine	6
1.2.2	The Cross Flow Turbine	8
1.2.3	The Propeller Turbine	9
1.2.4	The Pump as Turbine (PAT)	9
1.3	Field of PAT Application	13
1.3.1	Introduction	13
1.3.2	Natural Streams	14
1.3.3	Water Supply	16
1.3.4	Other Users	19
	References	25
<b>2</b>	<b>Reverse Pump Theory</b>	<b>27</b>
2.1	PAT Components	28
2.1.1	The Volute	28
2.1.2	The Impeller	29
2.1.3	The Draft Tube	30
2.2	PAT Theory	30
2.3	Flow Pattern in a Pump and in a PAT	33
2.4	Application of Computational Fluid Dynamics (CFD) to a PAT	36
2.4.1	Importance of CFD	36
2.4.2	Mathematical Approach	37
2.4.3	PAT Geometry Modeling and Mesh Generation	38
2.4.4	CFD Solutions for a PAT	42
2.5	Cavitation in a PAT	45
2.6	Pressure Surge Analysis in a PAT	48
	References	56

<b>3 Industrial Aspects of PAT Design Improvement . . . . .</b>	<b>59</b>
3.1 Impeller Refinement . . . . .	60
3.1.1 Rounding of the Blade's Leading Edge and the Hub/Shroud Inlet Edges of a PAT . . . . .	60
3.1.2 Impeller Diameter (Trimming Effect) . . . . .	62
3.2 Inlet/Outlet Part Refinement . . . . .	62
3.3 PAT Reliability . . . . .	65
3.4 PAT Life Cycle . . . . .	70
References . . . . .	72
 <b>Part II PAT Based Micro/Pico Hydropower Stations</b>	
<b>4 PAT Selection . . . . .</b>	<b>77</b>
4.1 Theoretical and Practical Methods . . . . .	77
4.2 Estimation of Characteristic Curves . . . . .	83
4.3 Rotational Speed Selection . . . . .	87
4.4 Impeller Diameter Selection . . . . .	88
4.5 PATs in Parallel . . . . .	88
4.6 PAT-Pump Direct Coupling . . . . .	90
References . . . . .	95
<b>5 PAT Control Systems . . . . .</b>	<b>97</b>
5.1 Operating Conditions in a WSN . . . . .	98
5.2 PAT Working Conditions . . . . .	103
5.2.1 The HR Mode . . . . .	104
5.2.2 The ER Mode . . . . .	104
5.2.3 The HER Mode . . . . .	105
5.2.4 The SSP Mode . . . . .	106
5.3 Plant Effectiveness . . . . .	108
5.3.1 System Capability . . . . .	108
5.3.2 System Reliability . . . . .	109
5.3.3 System Flexibility . . . . .	110
5.3.4 System Sustainability . . . . .	110
5.4 PAT Selection . . . . .	111
References . . . . .	116
<b>6 Civil Engineering Design, Electromechanics, Installation and Operation . . . . .</b>	<b>117</b>
6.1 Civil Engineering Design . . . . .	117
6.1.1 Intake and Turbine Inlet . . . . .	118
6.1.2 The Powerhouse . . . . .	121
6.1.3 Turbine Outlet . . . . .	123
6.2 Mechanical Components . . . . .	123
6.2.1 The Shaft . . . . .	125
6.2.2 The Shaft Seal . . . . .	125

6.2.3 The Bearing . . . . .	126
6.2.4 The Coupling . . . . .	127
6.3 Electrical components. . . . .	127
6.4 Installation Procedure . . . . .	133
6.5 Operation and Maintenance . . . . .	135
References . . . . .	136

## Part III Applications and Impacts

<b>7 Location of a PAT in a Water Transmission and Distribution System</b> . . . . .	139
7.1 Selecting the Site . . . . .	140
7.2 Flow Rate and Head Measurement. . . . .	142
7.3 Pressure Control in Water Transmission Systems . . . . .	147
7.4 Identification of Dissipation Points . . . . .	148
7.5 Dynamic Control of Pressure . . . . .	152
7.6 Numerical Methods . . . . .	154
7.6.1 Hydraulic Modelling . . . . .	154
7.6.2 Control Valves . . . . .	156
7.6.3 Runaway Conditions . . . . .	159
7.7 Pressure Surge Control . . . . .	161
7.7.1 Basic Considerations . . . . .	161
7.7.2 PAT Shutdowns with Control Valve Closure . . . . .	167
7.7.3 PAT Start-Up and Control Valve Opening . . . . .	168
7.7.4 Overspeed Effect in a PAT . . . . .	168
References . . . . .	169
<b>8 PAT System Economic Analysis</b> . . . . .	173
8.1 Fundaments . . . . .	174
8.2 Time Value of Money . . . . .	176
8.3 Methods of Economic Evaluation. . . . .	178
8.3.1 Net Present Value (NPV) . . . . .	179
8.3.2 Benefit/Cost Ratio (B/C) . . . . .	179
8.3.3 Internal Rate of Return (IRR) . . . . .	179
8.3.4 Payback Period (T) . . . . .	180
8.3.5 Economic Feasibility . . . . .	180
8.4 Effects of the Lifetime Cycle . . . . .	181
References . . . . .	186

<b>9 Application of PAT Technology . . . . .</b>	189
9.1 Working Plants . . . . .	190
9.1.1 Malecòn, Spain . . . . .	190
9.1.2 San Vito di Cadore, Italy . . . . .	194
9.1.3 Capodacqua, Italy . . . . .	197
9.1.4 Conejeras and Cartuja, Spain . . . . .	199
9.1.5 San Antonio, Chile . . . . .	200
9.1.6 Beliche, Portugal . . . . .	202
9.2 Pilot Plants . . . . .	204
9.2.1 Naples, Italy, Pilot Plant . . . . .	204
9.2.2 Lisbon, Portugal, Pilot Plant . . . . .	208
References . . . . .	217



<http://www.springer.com/978-3-319-67506-0>

Pumps as Turbines

Fundamentals and Applications

Carraffa, A.; Derakhshan Houreh, S.; Ramos, H.M.

2018, XV, 218 p. 209 illus., 120 illus. in color.,

Hardcover

ISBN: 978-3-319-67506-0